Instructional Strategies Integrating Cognitive Style Construct:

A Meta-Knowledge Processing Model

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Instructional Strategies Integrating Cognitive Style Construct:
A Meta-Knowledge Processing Model

Volume 1

Contextual Components that Facilitate Spatial/Logical Task Performance:

An Investigation of Instructional Strategies that Facilitate the Learning of Complex
Abstract Programming Concepts Through Visual Representation
Preface

Paradigmatic Approaches to Asynchronous Learning

Electronic communications technology is widely believed to offer new options, based on a paradigmatic approach, to the individualised instructional requirements of diverse cohorts of students. More specifically, multimedia and Web courseware development is seen to accentuate a presumed requirement for highly graphical (or visual) approaches to instructional formats. While most electronic courseware may allow the user to proceed at their own pace, the assumption is commonly made by designers of instructional material, that to facilitate learning, all users are capable of assimilating the graphical material with their current knowledge. There is little or no consideration for different cognitive styles!

There is a consequential need to accommodate co-existing instructional paradigms in any computerized learning/course authoring processes. This inevitably requires the dynamic evaluation of task knowledge level requirements to respond to individual cognitive styles and to deduce the student’s knowledge acquisition requirements. Meta-knowledge acquisition strategies are thus essential to provide the mechanism for dynamic knowledge analysis and for knowledge-mediated instructional processes.

This research will clearly identify the complexity of the visual learning environment, and outline prospects for a customised learning shell, based on meta-knowledge. Progress is thus possible in linking research outcomes to actual learning contexts. The prospect of customised learning shells, tailored dynamically to the requirements of individual students, has stimulated contemporary research into knowledge mediation, and the associated meta-knowledge acquisition strategies, of actual learning contexts within asynchronous learning frameworks.

Within the context of online asynchronous learning platforms, there is a noticeable shift from traditional teaching methods, which act as the sole content provider, towards a multiple mentor-guiding approach. This approach supports learners through the process of knowledge acquisition, largely directed by the learners themselves, reflecting the lack of understanding of the effect of computerized learning
on the population at large. The computer-human interface is complex, and instructional designers will need to ensure that careful attention is paid to sound and well-founded instructional design principles. In general terms, online courseware designers will need to be aware of the meta-knowledge acquisition process, relevant instructional strategies, and need to articulate the conditions-of-the-learner; specifically, a comprehensive model to direct the online learning experience that best achieves a high quality instructional outcome.

While multi-sensory instruction is known to improve a student’s capacity to learn effectively, the overarching role of knowledge-mediated, human-computer interaction has been poorly understood in the design of instructional strategies that integrate contextual components in asynchronous learning frameworks. Strategies for capturing this meta-knowledge are, however, poorly addressed by contemporary learning environments.

The limitations of contemporary approaches to instructional design appear to lie in the failure to recognise and accommodate learning process dynamics, specifically the interactive effects between cognitive style and instructional format and the need to adapt the instructional format dynamically. It may be concluded that the mechanism to achieve such dynamics lies in the concurrent acquisition of knowledge about the learner’s cognitive performance within a contextual framework defined by a knowledge level analysis of task difficulty.

This thesis presents the meta-knowledge support for a paradigmatic approach towards a customised learning environment. Aspects of instructional science, cognitive psychology and educational research are combined to articulate the meta-knowledge requirements. To accommodate these normally disparate disciplines, the author has diverged from the conventional thesis structure (cf. APA Guidelines), thereby offering an approach to research reporting more appropriate to the paradigmatic requirements. While the usual rigors of empirical research methodology have been followed, the level of sophistication relating to the thesis layout reflects the requirement for a meta-knowledge model. Each chapter may be read in isolation from the complete work, and therefore, it may appear that various concepts are covered a number of times, in separate ways. This is the intention in offering a layout design appropriate to multiple viewpoints. Naturally, the author hopes that this research perspective will generate considerable interest in the relationships between cognitive psychology, educational research and instructional science, which have not previously been elaborated in a unifying context or meta-knowledge framework.
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McKay, E. (2000a). Breaking down the mythology surrounding cognitive style and instructional format, *Computer Education* June. 3-9, UK.


**Invited International Conferences and Workshops**

McKay, E. (1998). Graphical Metaphors: Are they really worth a thousand words? Workshop presented at the *Tenth Annual Instructional Technology Institute, Automating Instructional Design Should we? Can we? Will we?* held 9-12 September, Utah State University, USA.


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The overarching goal of this dissertation was to evaluate the contextual components of instructional strategies for the acquisition of complex programming concepts. A meta-knowledge processing model is proposed, on the basis of the research findings, thereby facilitating the selection of media treatment for electronic courseware. When implemented, this model extends the work of Smith (1998), as a front-end methodology, for his glass-box interpreter called Bradman, for teaching novice programmers.

Technology now provides the means to produce individualized instructional packages with relative ease. Multimedia and Web courseware development accentuate a highly graphical (or visual) approach to instructional formats. Typically, little consideration is given to the effectiveness of screen-based visual stimuli, and curiously, students are expected to be visually literate, despite the complexity of human-computer interaction.

**Visual literacy is much harder for some people to acquire than for others!**

(see Chapter Four: Conditions-of-the-Learner)

An innovative research programme was devised to investigate the interactive effect of instructional strategies, enhanced with text-plus-textual metaphors or text-plus-graphical metaphors, and cognitive style, on the acquisition of a special category of abstract (process) programming concept. This type of concept was chosen to focus on the role of analogic knowledge involved in computer programming. The results are discussed within the context of the internal/external exchange process, drawing on Ritchey's (1980) concepts of within-item and between-item encoding elaborations.

The methodology developed for the doctoral project integrates earlier research knowledge in a novel, interdisciplinary, conceptual framework, including: from instructional science in the USA, for the concept learning models; British cognitive psychology and human memory research, for defining the cognitive style construct; and Australian educational research, to provide the measurement tools for instructional outcomes.
The experimental design consisted of a screening test to determine cognitive style, a pretest to determine prior domain knowledge in abstract programming knowledge elements, the instruction period, and a post-test to measure improved performance.

This research design provides a three-level discovery process to articulate:

1) the fusion of strategic knowledge required by the novice learner for dealing with contexts within instructional strategies

2) acquisition of knowledge using measurable instructional outcome and learner characteristics

3) knowledge of the innate environmental factors which influence the instructional outcomes

This research has successfully identified the interactive effect of instructional strategy, within an individual's cognitive style construct, in their acquisition of complex programming concepts. However, the significance of the three-level discovery process lies in the scope of the methodology to inform the design of a meta-knowledge processing model for instructional science.

Firstly, the British cognitive style testing procedure, is a low cost, user friendly, computer application that effectively measures an individual's position on the two cognitive style continua (Riding & Cheema,1991).

Secondly, the QUEST Interactive Test Analysis System (Izard,1995), allows for a probabilistic determination of an individual's knowledge level, relative to other participants, and relative to test-item difficulties. Test-items can be related to skill levels, and consequently, can be used by instructional scientists to measure knowledge acquisition.
Finally, an *Effect Size Analysis* (Cohen, 1977) allows for a direct comparison *between* treatment groups, giving a statistical measurement of how large an effect the independent variables have on the dependent outcomes. Combined with *QUEST*'s hierarchical positioning of participants, this tool can assist in identifying preferred learning conditions for the evaluation of treatment groups.

By combining these three assessment analysis tools into instructional research, a *computerized learning shell*, customised for individuals' *cognitive constructs* can be created (McKay & Garner, 1999).

While this approach has widespread application, individual researchers/trainers would nonetheless, need to validate with an extensive pilot study programme (McKay, 1999a; McKay, 1999b), the *interactive effects* within their specific learning domain. Furthermore, the instructional material does not need to be limited to a *textual/graphical* comparison, but could be applied to any two or more instructional treatments of any kind. For instance: a *structured* versus *exploratory strategy*. The possibilities and combinations are believed to be endless, provided the focus is maintained on linking of the *front-end identification of cognitive style* with an improved performance outcome.

My in-depth analysis provides a better understanding of the *interactive effects* of the *cognitive style construct* and *instructional format* on the acquisition of abstract concepts, involving spatial relations and logical reasoning.

In providing the basis for a *meta-knowledge processing model*, this research is expected to be of interest to educators, cognitive psychologists, communications engineers and computer scientists specialising in *computer-human interactions*. 
A mechanism is needed - a key - to unlock the *instructional strategies*, which remain impenetrable to some novice learners.

"Suddenly she came upon a little three-legged table, all made of solid glass; there was nothing on it but a tiny golden key, and Alice's first idea was that this might belong to one of the doors of the hall; but, alas! Either the locks were too large, or the key was too small, but at any rate it would not open any of them. .......... ......" Caroll (1907:7)
Various researchers have proposed that verbal (text-based) instruction suits a verbal-cognitive-style best, and that pictures (graphical-representations) suit an imagery-cognitive-style best (Riding & Douglas, 1993; O'Halloran & Gauvin, 1994). There is agreement that we need to offer individualized learning environments (Ausburn & Ausburn, 1978; Laurillard, 1993; Middleton, 1999). While there are many valuable contributions that have progressed effective use of media in teaching and learning (Makins-Slaughter, 1990; Gibbons & Fairweather, 1998); there are no courseware design models that cater effectively for the differences in cognitive style.

This thesis proposes the components for building a meta-knowledge processing model (Figure: 1.1), filling the current void in courseware design. It extends the work of Smith (1998) when implemented as a front-end methodology for the Smith's Bradman (glass-box interpreter) for teaching novice programmers.

The chapters of the thesis adopt a standard writing format involving a general introduction, as above, followed by a hierarchical organization of sections, sub-sections and relevant topics. Therefore the first sections involve:

- Background to concept learning
- Focus of the study
- Learning aids
- Research questions
- Thesis overview
Chapter One: Introduction

1. Background to Concept Learning

This thesis investigates the interactive effects of instructional strategies on the cognitive performance of learning abstract computer-programming concepts. Reactions of adult-learners to self-paced learning materials were studied in an Australian University context. The findings are used to develop robust instructional strategies for application in learning/training sectors.

1.1 Verbal Approach

There has been a traditional view that learners adopt a generic approach to make the learning of new abstract concepts meaningful. For instance: according to Tessmer, Wilson & Driscoll (1989), the intellectual skill associated with absorbing concepts should be included with the verbal information conveyed during instruction.

While Merrill, Tennyson & Posey (1992) explained that the cognitive processes, which are involved in learning concepts, are generalization and discrimination. Individuals generalise from a particular response to learning, to their overall learning experience. They suggested that learners look for common attributes that new concepts share with previously encountered ones.

The verbal (text-based) instructional strategies used in the final experiment were designed drawing on the Merrill et al.’s (1992) concept learning research.

There are three different forms of representation to consider when planning for the teaching of concepts according to Merrill et al. (1992); referent, isomorphic, and symbolic. The referent-form refers to the concrete representation of an actual object, event or symbol. The isomorphic-form may be an abstract representation in a picture or model that relates to the literal representation. Interestingly, a concept’s referent may not always be present. For instance: the screen display of a computer-interface can correspond between the graphical-representation of the concept, and the attributes of the referent to be learned. The symbolic-form describes the concept’s referent-form through words. Furthermore, there may be no correspondence at times, between the referent-symbol and its attributes, according to Merrill et al. (1992).

In relation to learning simple computer-programming concepts, Mayer (1979) conducted a series of experiments. He studied the effects of advance organisers on the responses of college students with no prior programming experience. Advance organisers were deemed to be instructional strategies which assist with the learning process (see also Ausubel, 1962).
Focus of the Study

Generally, advance organisers are presented prior to learning a larger body of material. They comprise a condensed version of verbal or visual information, which contains no specific content from the larger body of material to-be-learned. However, they provide a means of drawing out in a visual sense, the logical relationships from the separate instructional elements, thereby influencing a learner's cognitive encoding process (Mayer, 1979).

1.2 Visual Approach

There is some evidence relating to how an individual’s initial mental construct might take the form of a graphical image (Klausmeier, 1992). That image could serve as a device for mental recognition if the actual object has been seen earlier. Furthermore, mental constructs include the perceptible and non-perceptible attributes of the concept and the cultural meaning given to the name of that concept.

However, there are few examples of research that make a connection between learning abstract computer-programming concepts and graphical-representation as an instructional strategy. For instance: Neufield, Kusalik & Dobrohoczki (1997) have devised a colour coding process to trace programming logic flow; Smith (1998) has developed an interactive system, which traces the hidden activities of a computer-programming interpreter.

2. Focus of the Study

The foregoing research highlights the changes, which have been taking place in computerised learning environments.

This thesis extends the Bagley (1990) research on Structured Versus Discovery Instructional Formats for Improving Concept Acquisition by Domain-Experienced and Domain-Novice Adult Learners; by combining the interactive effects of instructional strategy and the cognitive style construct (Riding & Cheema, 1991).

There is an increased awareness of the need for technology driven courseware, prompting the revision of instructional strategies to respond to this trend. Computer literacy has become a fundamental skill in developed countries throughout the World. Therefore, instructional strategies, which accommodate different cognitive styles, are needed.
According to Rohwer (1980), some learners need help to develop their cognitive skills, while others merely need help in increasing their elaborative skills.

This thesis represents a synthesis of literature from a number of research fields including:

- **Instructional Science** (which involves the concept learning)
- **Cognitive Psychology** (which focuses on human memory research) and **Individual Learning Methodologies** (for cognitive style investigations)
- **Graphical Literacy** (which represents a wider spectrum of relatively new research).

### 2.1 Instructional Strategies and Cognitive Style

This chapter introduces the notion of visualisation as a form of mental process that individuals use in learning abstract concepts. A visual language exists, according to Hortin (1980); individuals can and often do think visually, and they can and do learn visually. Consequently, they can and should where appropriate, express themselves visually.

It would therefore seem to be a straightforward proposition that adding graphical material to textual material would enhance adult learning, particularly regarding learning new abstract programming concepts.

However, there is empirical evidence on the interactive effect of graphical enhancements to text-based learning materials. In general, researchers appear to be reluctant to say which mode of instructional strategy is more effective. Although, a distinction is made between learners’ different cognitive styles when Riding & Mathias (1991:384) say:

"where there is both verbal and visual material available to convey a particular topic then there is evidence that Verbalisers learn best when the textual description is presented before the pictorial illustrations, while Imagers prefer to see the illustrations before reading the textual information".

Furthermore, Riding & Caine (1993) reveal verbalisers prefer and perform best on verbal tasks. While imagers are superior on concrete, descriptive and imaginal ones. When there is a mismatch between cognitive style and instructional material, or mode of presentation, they have been able to show that performance is reduced.
Focus of the Study

Much is said about children’s learning in a wide variety of fields of education; however, there is a lack of adult-learning research.

The meta-knowledge processing model will enable adult-learners to benefit from the richness of their prior experiences when learning new abstract concepts. This is particularly relevant for courseware designers involved in developing training programmes for a diverse and multi-skilled workforce.

Until now, assumptions have had to be made by the instructional designer about how individuals will interpret the instructional material. For instance: little is known about adult-learning in the field of abstract programming concepts.

Moreover, there is evidence of disagreement in the literature when, according to Levie & Lentz (1982), pictures seem to have no effect on learning how to read, while Riding & Douglas (1993) state that Imagers represent information in a picture mode. Therefore, their learning performance seems to suffer when information is presented in a textual mode. Conversely, their learning performance seems to be enhanced when the instructional material is presented in a pictorial mode.

Furthermore, Winn (1981) expects the ability of learners to identify concepts to be better, when pictures, rather than block-word diagrams are used. Especially if the critical attributes of the concepts were emphasised in some manner (Merrill & Tennyson, 1977; Gagne, 1985).

Measuring the cognitive performance to provide researchers with a fine-grained analysis is now possible. This means that reliable tests can be given to determine the effectiveness of particular methods of instruction for particular instructional outcomes for individuals with a specific cognitive style.

There is a primary distinction between a visual and non-visual thinking person (Moore & Bedient, 1986). The former can retain visual-imagery while the other cannot. These researchers represent a considerable number of others who believe similarly.

In an earlier study, Moore (1985) proposed that presentation of multiple images should enhance the ability of wholist (or field-dependent) individuals to learn visual-tasks. Furthermore, he suggested that designers of instructional media should take this into consideration when designing graphical materials, because wholist individuals tend to
fuse the segments of a graphical-field and do not see parts discretely. According to Witkin, Moore, Goodenough & Cox (1977), they also tend to organise information into loosely clustered wholes. According to Moore & Bedient (1986), wholist individuals might score better on recall of graphical stimuli such as line drawings, which are less complex and less distracting than photographs or paintings.

On the other hand, analysts (or field-independent) individuals are able to impose a structure on unstructured learning material. They tend to organise information into clear-cut conceptual groupings according to Witkin et al. (1977).

Douglas & Riding (1993) suggest however, that it may be desirable to provide individuals with information of their cognitive style. This would allow learners to recognise situations in which they may have particular difficulty regarding learning, and thereby enable them to remedy the problem.

There are some circumstances where a novice-learner simply cannot evaluate the instructional outcome correctly. Therefore, it is desirable that the instructional strategy is appropriate for their knowledge requirements.

Some research has been conducted taking a generic approach to the effects of cognitive style on instructional format, by concentrating solely on the interaction of instructional strategy that involve a combination of verbal (text-based) and pictures.

For instance: Solman, Singh & Keohe (1992) and Wu & Solman (1993), have argued that the interference of pictures with written words may be attributed to a blocking-effect. They showed the standard instructional procedure of presenting pictures and written words as compound blocks are believed to detract from learning. However, they did not rule out the possibility that the information pictures contain may be used to advantage, or that this visual information may, at least, be used in a way which can overcome a blocking effect. Consequently, given the results of these and previous studies, and in the absence of a compelling reason for the inclusion of extra pictorial stimulus prompts, Wu & Solman (1993) recommended their removal.

The findings, which emerge from this thesis, may well provide this compelling reason, given the nature of the interactivity effect of the cognitive style construct on measurable instructional outcomes.
However, research identifying the individual's mode of thinking has shown a different outcome to that of Wu & Solman (1993). In relation to a preferred cognitive style and imagery training O'Halloran & Gauvin (1994) also believe that individuals who prefer to think using pictures, rather than words, would benefit more from mental-imagery than people who prefer to use words. They tried to demonstrate this benefit by showing an interactive effect of an improved performance on a novel motor-task, with an improvement in imagery vividness. They were unable to show this effect. Subsequently, their research provides an interesting insight into the role of individual differences in cognitive style. For instance, it is possible that regardless of the treatment conditions, individuals who think using pictures, mentally rehearse their tasks. Their subjects were led through an imagery process, by an internal dialogue. O'Halloran & Gauvin (1994) suggested there may have been a mismatch between the task requirements and the subjects’ cognitive styles; therefore, supporting the role of a preferred cognitive style in imagery training.

In looking at mathematics ability and cognitive styles; Riding, Buckle, Thompson & Hagger (1989) found that the low-ability verbalisers, in a mathematical group did substantially better with textual information than with pictorial materials. They also found that the imagers were the reverse of this, performing better on the appearance information. The conclusion from Riding et al. (1989: 396) was:

"the results from the high ability group suggest that it is possible to identify certain students who, despite being able mathematically, might be in danger of paying insufficient attention to appearance information. Such students are fast in responding verbally, but have relative difficulty in making decisions about appearance information comparisons".

According to Dwyer & Moore (1991), the individual’s measure of wholist (field-dependence) and analytic (field-independence), have become important variables to instructional designers. Their relative position on this continuum reflects the degree to which a learner will interact with a graphical presentation. Further, it shows whether the learner will interact merely with the instruction as presented; or whether they will analyze, reorganize and synthesize the instruction to make the learning content more meaningful and memorable (Ausburn & Ausburn, 1978).

Apparently, an individual’s cognitive style is more comprehensive than first thought, according to Riding & Caine (1993). They described cognitive style as a combination of two-continua: Wholist-Analytic and Verbaliser-Imager. Therefore, the visual structure of learning material is likely to affect individuals differently.
For instance: *Analytic-Imagers* and *Wholist-Verbalisers* can keep a balance between the whole of the information and its discrete parts. While the *Analytic-Verbalisers* will benefit more from an emphasis on the discrete elements to be learned, the *Wholist-Imager* will not pick up fine detail, but will understand the information to be learned, as one whole element. They predicted that all O-level secondary college students in Britain’s GCSE were likely to require assistance with both the identification of individual learning elements, and the integration into, or perception of, the whole of the information to be learned.

Prior to this thesis, the evidence was sparse for identifying which mode of instructional presentation suits which cognitive style best. Accordingly, the research plan has been designed to show which combination of the cognitive style construct has superiority (if any), for instructional strategies that include pictures as well as text.

2.2 Superiority of Verbal vs Picture Formats

Rosch (1975-a) proposed that pictures could be prepared for perception more quickly than words. Her research investigated whether cognitive representation forms as concrete images, or conversely, whether an individual’s thought processes are actually abstract and imageless. Her work pursued the broader question of whether all meanings of our World, have a common abstract form, notwithstanding their context; or whether these meanings are represented in a number of ways.

For instance: text and graphics may require different mental processing. In fact, she produced evidence of differences in processing verbal and pictorial forms. Riding & Caine (1993) were in support of this by suggesting that picture representations are generated more rapidly than the representations for words. These experiments were investigating higher-order (or superordinate) classifications of concrete objects.

In relation to the effects of age, Rosinski, Pellegrino & Siegel (1977) suggested that we process pictures faster than words, and this difference declines with age. For instance: they experienced with second-and fifth-grade subjects an increase in both the absolute and relative speed of verbal access to the semantic-memory base with an increase in age.

In relation to the learning of abstract nouns, Paivio, Yuille & Smythe (1966) use the term imagery to describe an individual’s ability to think graphically. For instance: they believed that an individual’s use of *imagery* is inferior to *verbal-learning*. This inferiority is due to the difficulty individuals have in producing an image of an abstract
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picture and word pair. Furthermore, they believed this phenomenon only occurs when an individual is required to produce an abstract picture and noun word pair. However, Paivio & Forth (1970) suggested that it is easier to imagine word and picture pairs when they are concrete nouns. Ernest & Paivio (1971) proposed the necessity of imagery in tasks involving a memory component.

The learning of computer-programming concepts involves the use of imagery during the reading event and the application of the newly learned concept.

Sheehan & Neisser (1969) found a high correlation between ratings of the vividness of imagery and the accuracy in recalling material that was presented by chance or incidental learning. Ernest & Paivio (1969) also reported a positive relationship exists between imagery ability and incidental learning in what they called a paired-associate task. This relationship occurs when the word compounds represent the concept of colour. They found that high imagery ability was positively related to learning in their female sample. Whereas the converse was found with males. Furthermore, Ernest & Paivio (1971) made a rough generalization when suggesting females perform better than males on verbal-tasks (like verbal fluency, articulation and spelling), while males are superior on visuospatial-tasks (like maze learning and form-board tasks).

Meanwhile, a differing view was expressed by Fleming (1962); textual presentation is favoured, even when there is text with a pictorial display that is equally or more valuable. However, this preference of textual learning materials may be due to inadequate training in the interpretation of pictorial material, in the traditional learning environment (Rohwer, 1980; McNamara, 1987).

3. Learning Aids

It is important that instructional materials have a good balance between verbal and visual messages, as well as providing the opportunity for practical, hands-on-exercises (Pettersson, 1993-a).

3.1 Verbal

Generally, research into verbal learning aids ignores the issue of the complexity of learners’ cognitive style. However, this earlier work is nonetheless a valuable
contribution. Instead concentration was given to a generic interaction between the instructional materials and learner performance.

For instance: Ausubel (1962) presented a theory of cognitive organization, long-term learning and retention of large bodies of meaningful, verbally presented material. This theory, he admitted did not include perceptual learning. He evaded this issue, claiming there are different explanations to account for that type of learning. Furthermore, he paid no attention to the individual differences in cognitive capacity of the learner and their orientation to learning.

However, Holliday, Brunner & Donais (1977), suggested that science diagrams have the potential to present a scientific pathway or cyclic schema, by condensing a sequential chain of *verbal-labels* described in the text. They investigated differential cognitive and affective responses made by high school biology students and teachers toward two different flow diagrams: a *picture-word diagram* and a *block-word diagram*. Their block-word flow diagram was adopted from Gropper's (1970) *big picture* verbal diagram and their picture-word flow diagram was adopted from Spangenberg's (1971) coherent diagrams.

Furthermore, Glynn, Britton & Tilman (1985) extended the approach taken by Crouse & Idstein (1972), when they concentrate on typographical cues in text as a management strategy for maintaining the reader's attention (Glynn, et al.,1985:207).

"Readers cope with the limited capacities of their working memories by selecting the most important information for extensive processing and by organizing this information into hierarchically-related conceptual categories. Typographical cues can help readers to identify, organize, and interpret the most important content in a text."

They defined these cues as *italics, boldface, arrows, colour, boxes*, and *white space*. Furthermore, they encouraged authors to keep in mind three guidelines when planning their typographical cues:

1) use a cue only when its purpose is perfectly clear  
2) use a cue sparingly  
3) avoid a complicated cue

Gropper (1970) also avoided the issue of learner differences when he implemented *verbal diagrams* to condense learning material. These diagrams contained: *verbal-labels, short-phrases, block-figures (or verbal diagrams)* and *arrow-lines with instructive questions*. However, he found that *verbal-diagrams* with instructive questions were more effective than conventional instruction.
Moreover, Holliday (1976) used singleflow diagrams and texts for recall of sequential chains of verbal-labels. He predicted that a flow-diagram would be more effective than an instructional medium that combined diagram and text.

3.2 Visual

Research into visual learning aids also appears to ignore the possibility of an interactive effect of a learner’s cognitive style, on the presentation of learning materials. Although there is evidence of a few connections made between the traditional approaches to instruction, which use text based materials, and the obvious need to investigate the effect of adding graphics.

For instance: Paivio & Csapo (1973) predicted line-drawings of concrete concepts, or the repeating of a word, facilitated verbal recall, especially in verbally deficient learners. Moreover, Kirby & Schofield (1990), put forward a conjoint retention model, which refers to the relation between maps (graphical representation) and text. They claimed such displays appear to facilitate verbal memory, within a variety of different subject matters, and across a wide range of ages.

Rosch (1975-b) showed a textual-cue used as a priming technique, can have both proactive and reflective effects on an individual’s decision-making processes. Although this device she admitted, can only have an effect on a learner’s response if it contains some of the information needed for the response. She assumed that using a priming technique affects visual encoding.

For instance: using physically identical pairs of common use English nouns as her stimuli (fruit, bird); she believed there are only two mental operations an individual can make on these pairs:

1) the perception or visual encoding, which is a form of linguistic or imaginal transformation of her stimuli

2) the perception that the members of the stimulus pair are identical

Accurate measurement of the effects of visual cueing mechanisms on cognitive performance is needed to establish whether there are differences in reactions to a graphical instructional delivery method.

There have been a number of different ways visual cueing mechanisms have been described in the past. For instance: Holliday et al. (1977) explained that imagery was generally viewed as a metaphorical model of coding and remembering, in terms of dynamic
perceptual images of things and events, when accompanied by verbal-labels. While Reigeluth (1983-a) described embedded-activators, which included: pictures, diagrams, mnemonics, and analogies.

However, according to Merrill et al. (1992), simplified illustrations, such as line drawings, can emphasize only the critical-attributes. Their attention-focusing devices included: colour, exploded drawings, special symbols, written or audio notes, simplified illustrations and motion video. Cognitive processing they suggested, only helps individuals who use the most appropriate cognitive strategy in a way consistent with the desired learned performance.

This thesis aims to distinguish between the individuals who benefit from visual enhancements and those who do not.

In a discussion on symbols and symbol systems that convey information, Salomon (1979) proposed that any object, movement, mark, or event can potentially serve in a symbolic capacity as long as it can be taken to represent, denote, or express something beyond itself.

In the same sense, Rosch & Mervis (1975) described this relationship as the natural prototype structures to which individuals reliably categorize, according to their own idea or image of the meaning of a category name. The single-symbol-element needs to be imbedded into a symbol-system in order for interpretation (Salomon,1979). Misinterpretation can occur, however, when the same symbol-element is imbedded into two different contexts.

Kulhavy, Stock, Peterson, Pridemore & Klein (1992) tested their conjoint retention model by having undergraduates learn an intact map and text. They investigated whether their subjects could then see this map as a retrieval-cue, in either its original form or in a reorganised format. They were interested in finding out whether people can use visual-displays to improve memory for related verbal-information.

This thesis will differentiate between the types of cognitive skills and knowledge performance levels required by the instructional outcomes.

3.3 Mnemonics

History shows visual-displays were used by ancient cultures, to convey meaning. For instance: the ancient Greeks and Romans used mnemonics. They should be introduced into educational curricula (Levin,1981-a).
Levin (1981-b) reviewed the potential of stretching Atkinson's (1975) mnemonic *keyword method*, by combining it with other mnemonic and prose-learning strategies to enable the physical transformation of the *to-be-learned* materials, into a form that makes them easier to learn and remember.

There was a warning, however, due to the physical nature of the transformations (Levin, 1981-a), that mnemonics should not be thought of synonymously with general memory strategies. For instance: *rehearsal, semantic processing, clustering*.

**Given the rapid rise in the electronic delivery of information,**

*there is a need to identify the memory transfer processes involved while viewing text and graphics.*

Mnemonic strategies were described by Baine (1986), as being practical techniques which have the potential to make information more memorable and easier to retrieve. He described three mnemonic strategies: *labelling, visual-imagery, and maintenance rehearsal*. In so far as *visual-imagery* is concerned, he refers to numerous studies, which were conducted using children. However, most of these studies involved *directed visual-imagery* behaviours, with subjects being instructed to create images (Moore & Bedient, 1986).

Furthermore, Thompson (1990) was critical of mental-imagery-tests, where the subjects are deliberately pushed to form images, rather than leaving them to report on their normal way of thinking.

Baddeley (1990) also warned; that using mnemonics must be especially well designed. They are tools and as such, when used as internal (*memory*) aids, should be well-forged before use.
4. Research Questions

A number of questions are raised by this thesis. The main one being:

? to what extent do visual representation(al) instructional strategies enhance abstract concept learning for verbal and visual preferred learners?

An examination of these issues then gives rise to the following general queries:

? how to measure the effect of verbal expositional strategies on imagers?

? what effect do the visual representational strategies have on imagers?

? how does visual representation effect both the verbalizer and the imagers?

? what is the performance of both the verbalizer and imager, with both instructional strategies

? can a test of cognitive-skills-performance be used to identify weakness in an individual's entry-skill-levels, to predict retraining (reskilling) needs?

? how would an individual with a particular cognitive style be influenced by a particular instructional strategy?

A further question, relating more specifically to the computer-programming environment is:

? whether there are differences in the learning performance in structured programming, between text- and visually-enhanced instructional strategies?

In view of the increase in computerised learning media, this problem is of particular interest. Instructional designers often devise materials intended as generic learning aids. In doing so, many novice-learners do not develop the fundamental cognitive skills associated with the new discipline. Therefore the question, which arises out of this premise, is:

? are such differences in learning performance related to cognitive style?
5. Thesis Overview

Chapter one introduced the main aims and a brief overview. It discussed the conventional view that verbalizers perform best with textual material, while imagers respond best with pictorial instructions. Several examples were given of the more important (relevant) research issues, to provide the reader with an understanding of the complexity of synthesizing viewpoints from disparate disciplines.

Chapter two sets the conceptual framework for developing instructional strategies to accommodate learner differences. The Riding & Cheema (1991) Cognitive Style Analysis (CSA) is explained. The CSA is used as a screening test to identify an individual’s cognitive style as a ratio, which is used to divide the participants for experimental purposes.

Chapter three presents a comprehensive review of the literature related to the instructional design and computer-human-interaction issues, such as:

- Knowledge and learning
- Instructional format
- Retention and instructional strategy
- Building electronic learning systems

Chapter four explains the special role of Reigeluth’s (1983-b) conditions-of-the-learner. These conditions describe the intricate instructional (learning) environment. A distinction is made in this chapter between the internal- and external-conditions-of-the-learner.

Chapter five describes the research methodology and experimental design adopted to bring together the required strategic knowledge elements. The chapter describes the research methodology and experimental design separately, to flush out the major influencing factors necessary to bring about a computer-mediated learning environment. A three-level strategic knowledge framework is used to articulate the research objectives. The first is the research process, which examines the initial question raised, concerning the effect of interaction of instructional format and cognitive style on the acquisition of abstract concepts. The second identifies the variables involved in the process of acquiring programming knowledge, while the third considers the special environmental or contextual factors that seemingly have an effect on the final outcomes.
Chapter six presents the hypotheses developed from the survey of related work. Included are the factors affecting results, and a description of the cognitive measurement tools employed to estimate the pretest and post-test performances. The QUEST logit scale (Qls) is used to quantify cognitive performance in terms of the instructional outcomes expressed as programming-knowledge-performance-bands (pkpb's).

The size effects (Cohen, 1977) of the interactivity between instructional-format and cognitive performance are discussed providing separate analyses of the Riding & Rayner (1998) cognitive style construct (Wholist-Analytic; Verbal-Imagery continua) in terms of single characteristics of cognitive style groups (SCCG), and the interactive cognitive style sub-groups (ICS).

Chapter seven concentrates on the contextual elements to analyse the findings. Speculative mechanisms are proposed to explain how individuals deal with differing instructional formats.

Chapter eight briefly suggests how the research results may be applied in customising electronic learning environments. A reflective analysis of the findings from the instructional science viewpoint, is then provided.

Chapter nine proposes three categories of conclusions derived from this research:

- refocussing published work
- spill-over benefits for the retraining sector through customised instructional mechanisms
- defined context for a theoretical framework for a meta-knowledge processing model (see Figure 9.2).

The next chapter presents the three research paradigms from which an innovative theoretical framework was derived for this study.
This chapter discusses the relationship between *cognitive style* and *instructional format*. The interdisciplinary nature of the conceptual framework used for this research represents a synthesis of literature from a number of research fields: instructional science, to encompass concept learning; cognitive psychology, to focus on individual learning, and human memory research.

Recent advances in technology now enable us to deliver electronic courseware. This instructional medium is often highly graphical, in the sense that explanatory text may be limited, if not completely replaced by images (or pictorial representations). Furthermore, there is an implied expectation made by instructional designers, using this relatively new instructional platform, that learners are visually literate. Although the literature now shows there is an apparent understanding of the need to provide for individualised courseware, the problem of how to bring about a more learner centred approach to instruction remains unsolved. For over a decade now, researchers have been struggling with this issue.

Due to the complexity of the issues involved, the discourse derived from the literature is divided into the following sections:

- **Instructional science paradigm**
- **Concept learning**
- **Instructional strategies under constant review**
- **Information processing**
1. Instructional Science Paradigm

There is limited evidence in the literature of research that directly links instructional strategies to individual differences in preferred learning modes. Ausburn & Ausburn (1978) noted, that if we were to move beyond *individual* instruction to *individualized* instruction, then consideration must be given to designing instruction that caters for *cognitive style* differences. Their research considered the interactive effect of a learner's preference for cognitive mode, the information processing elements (Bower, 1994) of the task requirements, and instructional strategies. For testing instructional strategies, they proposed a three-step supplantation-analysis process. Step one was an analysis of the learning task; step two involved a decision for whom the supplantation (or special instructional strategy) is to be given; step three determined how to implement the supplantation technique. They suggested this technique, which follows Cronbach & Snow's (1969) Aptitude Treatment Interaction (ATI) model, was an appropriate research methodology.

However, ATI is a hypothesis, which suggests that the most effective learning materials, or methods, are dependent on measurable learner characteristics, or aptitudes, such as imagery or verbal abilities. Although Holliday, Brunner & Donais (1977) suggest that ATI should be used as a tool to aid instructional designers, there are no effective methodologies put forward to effectively measure individuals' cognitive differences. Currently there is still a need for researchers to pay attention to the interaction of cognitive style and instructional format as identified by Ausburn & Ausburn (1978). They encourage further work on testing hypotheses that predict that learners with opposite cognitive styles will benefit, to differing degrees, from the same instructional strategies (Middleton, 1999). They suggest that this new research needs to investigate whether dissimilar cognitive styles will interact differently, resulting in superior performance by learners with one cognitive style under one condition of instructional strategy, and by learners of another cognitive style under a different condition of instructional strategy. They concur with Snow (1974) and Merrill (1994), in suggesting sound research designs limit the generalisation of treatment effects, thereby producing robust research results, rather than findings which are broad and all-encompassing.

A conceptualized relationship does exist between learner and task (Figure:2.1). This research sets out to identify and measure the cognitive performance of *novice computer-programmers* given simple problems to solve.
According to Ausburn & Ausburn (1978), it is this conceptualized link which is often responsible for inhibiting a learner's task performance. They suggested that a dual instructional process could form a bridge, to supplant certain learning processes individuals are unable to perform; to complete the learner/task link, and enable a successful task performance. The first process was a conciliatory supplantation; implemented through carefully designed prompts, to capitalise on the instructional mode used by the learner. Their second instructional process was a compensatory supplantation; it facilitated the task transformation, to enable the learner/task linkage, when task transformation was not possible through conciliatory means. For instance: the picking out of embedded items on a highly complex diagram. The connection has therefore been made between cognitive style and instructional strategy. However instructional design practitioners are left to devise their own material, and research still appears to proceed in a piecemeal fashion.

To explore coverage of those issues by the published literature, the following sub-sections include:

- Improving instructional strategies
- Visual/verbal instruction dilemma
- Goodman's notational language
- Generic attitudes to instructional strategies and cognitive abilities
- Linguistic/imaginal connection
- Perils of non-traditionalist instructional design
- Deficiencies of computerized instruction
1.1 Improving Instructional Strategies

Reigeluth, Merrill, Wilson & Spiller (1980) presented an Elaboration Theory of Instruction, as a model for sequencing and synthesising instruction. A new Component Design Theory (CDT), which included the Elaboration Theory, was proposed by Merrill (1987) to assist designers of computerised courseware. Furthermore, Merrill, Li & Jones (1991) developed the Instructional Transactions Theory (ITT). This courseware authoring model represents an instructional design framework which included: instructional transactions (the algorithms incorporating patterns of learner interactions), and a transaction shell (interactions, parameters, and knowledge representations). This shell comprised two sub-systems for authoring and delivery, as distinct and separate environments. Consequently, Merrill and his collaborators led the way for instructional designers heading into the turbulent technological 1990's.

Thus began the second generation of the instruction design (ID2) paradigm. ID2 shifts the earlier emphasis from the behavioural components of instructional design, which relied on textual instructional strategies; towards providing technological learning environments, which concentrate on cognitive processing. Reigeluth & Garfinkle (1994) also point out the need for a complete overhaul of our thinking about educational requirements.

1.2 Visual/Verbal Instructional Dilemma

Research into visual literacy represents a wide spectrum of research, with a growing number of researchers from diverse disciplines, according to Seels (see Dwyer & Moore, 1994). Although a substantial amount of literature can be found in each separate research field, it does not generally adopt an inter-disciplinary approach. However, the field of cognitive psychology is now accepting evidence from experiments conducted in other domains, such as artificial intelligence (Breuer & Kummer, 1990; Muraida & Spector, 1993), and individual learning styles (Ramsden, 1992).

Research into diagram theory (combining text and pictures) was still in its infancy in the mid 1970's, according to Holliday (1976). Although no categorical recommendations could be made, he suggested instructional designers should seriously consider and investigate the use of single flow diagrams with instructive questions. For instance: flow diagrams were a more effective instructional medium than a text description (only for some learners performing some tasks), in explaining the same verbal chains. He found that research participants presented with flow diagrams, achieved higher scores than did the participants presented with the combination of diagram and text.
This research uses various visual display techniques to depict the complexity of programming logic flow (Figure:2.2) (for a full description of this technique, see McKay (1999b)).

1.3 Goodman's Notational Language

There was some evidence in the literature of attempts to link verbal/graphical displays, to explain the learning process. Spangenberg (1971) investigated a type of instructional diagram. His research involved presenting a diagram containing twenty-verbal (nonsensical) and twenty-line drawings (sensible) of integrated paired associates. He suggested that the single verbal line drawing is more effective than the other treatments. However, Holliday (1976) noted that Spangenberg's single diagram presented independent associated pairs that were spatially linked, whereas verbal chains are usually presented in a single flow diagram. This idea of spatial linking was also expressed as a notational (or direct) relationship, according to Goodman (1968).

The instructional strategies used for this research draw directly on the Goodman notation relationships, to devise the proposed meta-cognitive processing model for the knowledge acquisition process.

1.4 Generic Attitude to Instructional Strategies and Cognitive Abilities

Understanding an individual's response to instructional materials, in relation to their preferred cognitive style has proven difficult. For instance: Anderson (1970) only considered the presentation of two instructional media, textual- and flow-diagrams, without including the effects of cognitive style. Holliday (1976) also avoided the issue of measuring individuals'
cognitive differences, suggesting the problem appeared to be one of cognitive economy (Rosch, 1978), whereby learners will choose the least effort necessary to carry out a specific learning task. Without knowing their research participants’ cognitive style preferences Holliday et al. (1977) investigated differential cognitive and affective responses made by high school biology students and teachers toward two different flow diagrams: a picture-word diagram (which has both pictorial qualities and verbal representation) and a block-word diagram (which requires semantic coding). The block-word flow diagram investigated in this study was adopted from Gropper's (1970) big picture verbal diagram and the picture-word flow diagram was adopted from Spangenberg's (1971) coherent diagrams. Both these types of diagrams appear to have the similar non-notational characteristics as described by Goodman (1968).

1.5 Linguistic/Imaginal Connection

Holliday et al. (1977) hypothesize that highly verbal learners can utilize their verbal ability when learning science processes, from instructional materials containing relatively few pictures. Similarly, learners with lower verbal performance depend more on science pictures relevant to learning the critical information. There was evidence of support for this prediction from Dwyer (1972), who concluded that students would rather learn about the human heart from a coloured drawing than from an uncoloured display. To make these predictions, Holliday et al. (1977) used their Linguistic-Imaginal Model (LIM), a synthesis of the Paivio (1971) coding and memory hypotheses concerning images and verbal information, together with Cronbach & Snow's (1969) ATI hypothesis concerning individual learner differences.

1.6 Perils of Non-traditionalist Instructional Design

There was limited research into instructional strategies and individualised learning during the 1980's. Consequently, the instructional design effort, which digressed completely from the conventional text-based instructional models, towards the newer trend for non-textual instructional strategies, was possibly fruitless. The traditional instructional design view using textual based material was again reinforced with the introduction of technological solutions proposed for computer-assisted-instruction (CAI). These instructional strategies, appear to have brought the original tenets of instructional design ideology back in vogue (Merrill, 1998).

1.7 Deficiencies of Computerised Instruction

Tessmer & Jonassen (1988) suggested that CAI learning strategies represent strategies, whereby the learner has control over their learning environment. They assumed that the
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learner has control over the instructional method for their cognitive processing and in the recall of their knowledge during an instructional event. However, technology in this environment, forces the novice learner to adopt a generalised set of mental skills, as opposed to the development of instructional strategies to reflect learners experience when interacting with the more traditional types of instructional materials.

Merrill (1998) explained that technological courseware becomes expensive to implement based as it is on trial-and-error leading to hit-or-miss outcomes, which often overlooks effective alternative methods. There are prescriptive relationships among these variables. For instance, instructional strategy is the most important variable class. He defined a further three basic kinds of strategies: presentation, structure, and management. Researchers were advised by Merrill (1994) to be careful to specify the parameters of important variables. Similarly, he said that theorists must be careful to specify the parameters of the instructional situation and subject matter, when recommending instructional strategies.

2. Concept Learning

As the instructional content of this research is the acquisition of computer-programming concepts, it is necessary to define the terms. The term concept means different things to different people. Consequently, this discussion concentrates first on several different approaches taken by concept learning researchers in their use of the word. Following on from this are the views of researchers on the classification of concepts. Next, the characteristics of concepts highlight the range of theoretical frameworks used by researchers to base their hypotheses. Finally, four categories of concepts are presented to establish the theoretical position taken in this study.

2.1 The Term Concept Defined

Curiously, the literature revealed a struggle by researchers for a clear definition of the term concept. Some researchers assumed the term to be so self-evident as not to warrant clarification. Klausmeier, Ghatala & Frayer (1974) suggested that concepts were the fundamental agents of thought for human beings which develop during an individual's early childhood and continue to develop throughout their adulthood. Although Gagne (1985) agreed in principle with this notion, he argued that the term concept has several meanings. For instance: one of his meanings of the term, related to his work which concentrated on the individual's behaviour to object-qualities for names of things like: red, double, and circular; or common objects such as: cat, chair, and tree, in the sense
that their qualities can be pointed out. Another way he used the term *concept* was to refer to the abstract qualities of a concept, in the sense that they involve the *relations of the concept's qualities for physical concepts* like; mass and temperature. Other meanings of the term *concept* as described by Gagne (1985), were for language concepts like: subject and object. He also referred to the mathematical concepts of square root and prime number. Merrill (1994) confirmed the Gagne approach, in defining the term, by suggesting that individuals invent concepts as arbitrary categories to help them deal with the world. Martin & Briggs (1986) used the term *concept* in the plural sense and defined concepts as a subcategory of intellectual skill development.

Anderson & Faust (1973) recommended that the term *concept* be best described as a well-defined set of discriminative features of real world objects, events or ideas. This was the classical view of the term, according to Fleming & Levie (1993); which emphasised the stimulus characteristics, or well-defined common characteristics of all examples of a concept, both in an individual or collective manner. Ausubel (1968-a) took a different position within the classical understanding of the term, and made the distinction of an individual living in a world of concepts, rather than in a world of objects, events, and situations. He said we experience the world through a conceptual or categorical filter.

Pask (1984) entered the debate by explaining the notions of public and personal concepts. He described a public concept as comprising shared components of personal concepts. Klausmeier & Sipple (1980:22), appeared to agree with Pask when they defined a concept as:

".... both a mental construct of the individual and the societally accepted meaning of one or more words that express the particular concept. Concepts as mental constructs are the critical components of a maturing individual's continuously changing, enlarging cognitive structure and are the basic tools of thought".

However, Merrill, Tennyson & Posey (1992:6) were more pragmatic. Their definition of a concept was:

"A set of specific objects, symbols or events which are grouped together on the basis of shared characteristics, which can be referenced by a particular name or symbol".

They believed that concepts exist as interrelated sets, and they used a concept taxonomy to demonstrate the relationships among a set of related concepts. Klausmeier et al. (1974); Rosch (1978); and Merrill & Tennyson (1977) also described concept taxonomies. According to Merrill et al. (1992), concepts within the taxonomy can be
structured according to superordinate, coordinate (Tennyson, Tennyson & Rothen, 1980; Tessmer & Driscoll, 1986), and subordinate relationships to one another.

Gropper (1991) became involved in the debate on concept definition by expressing the view that there was considerable overlap in the performance requirements for defining concepts, giving explanations and applying facts. While not totally consistent with this view, a number of researchers postulated that individuals must recognize instances of concept class (Gropper, 1983; 1991; Gagne, Briggs & Wagner, 1988; Merrill et al., 1992). Gropper (1991) insisted that the instance class of the concept be defined in all three overlapped performance requirements, and might encompass objects, situations or ideas.

2.2 Concept Classification

Klausmeier & Sipple (1980) maintain that classifying concepts can occur in a number of different ways; one way is in accordance with the particular class of word used. They suggest these classes of words can then be further categorized to form classes of words, which represent concepts. Another way to classify concepts is in terms of the defining attributes that can be perceived (Nelson, 1974; Gagne, 1985); an example of this is the concept of a circle as described by Tessmer & Driscoll (1986).

Baine (1982) also suggested there were various types of concepts and defined them as unidimensional, multidimensional, and combinational. He listed five of the ten types as described by Haygood & Bourne (1965) and Bourne (1974), as being the most commonly occurring concepts, which are: affirmative, conjunctive, inclusive disjunctive, conditional and finally biconditional. Fleming & Levie (1993) presented a concept hierarchy, which is similar to the Baine (1982) model. However, while the Fleming & Levie (1993) hierarchy reflected the classical approach towards defining a concept, their hierarchy consists of four categories or groupings of concept type, based on: the structure of the concept attributes, perceptibility of the concept example, ease of the concept definition, and by relationship to other concepts in a hierarchical sense. They defined each concept category type in turn as conjunctive, disjunctive and relational, which closely reflects the description given by Baine (1982).

2.3 Concept Characteristics

Most concept research to date has been conducted on concepts that have perceptible, concrete or easily defined attributes (Glass & Holyoak, 1985). Merrill et al. (1992) called stimulus characteristics of concepts the critical (or criterial) attributes, while Tennyson & Cocchiarella (1986) called the other characteristics of concepts that were not shared by all members of the concept class, variable attributes. Merrill et al. (1992) further divided critical concept attributes into two categories: constant and variable. The former
category representing the legal values, were discrete and remained constant; the latter category were more complex, and while reflecting the legal values of a concept, can be depicted along a continuum or arranged on some other dimension. Variable attribute boundaries were not exact and were usually determined by the context in which they were presented (Tennyson & Cocchiarella, 1986) and may, in fact, overlap with the boundaries of another concept class.

The classical view of the term *concept* has been criticized in the literature. Most real world concepts have fuzzy boundaries (Wilson & Tessmer, 1990). Their attitude was supported by the Newby & Stepich (1987) view that concepts can be defined along a continuum according to their concreteness or abstractness. Fleming & Levie (1993) agreed with this, by suggesting that not all objects, events, or ideas have well defined characteristics. For instance, most adults would experience difficulty constructing a definition of the concept *cars*, that would include all examples and non-examples of that particular term. Furthermore, as Baine (1982) advised, we do not knowingly sort through a list of critical attributes, when considering a concept. Fleming & Levie (1993) reformulated the Baine (1982) notion, when they stated that both critical and variable characteristics of the object, event or idea are combined in a prototype (Rosch, 1978), which is a mental model (Tennyson, 1992-a) of the concept.

McKay (1999a) identified a total of 61 different programming concepts in a test instrument given to higher education students.

The four types of concepts referred in this thesis are now described.

- Concrete
- Defined
- Rule
- Process

2.3.1 Concrete concept

Concrete concepts are tangible things (Baine, 1982), and can be pointed out by their easily recognized characteristics (attributes) (Gagne, 1985). Such concepts are identified by observation (Gagne, 1970; 1985; Gagne et al., 1988). They have common physical features (Gagne, 1977) and are the things we can readily see, hear, feel or smell (Newby & Stepich, 1987; Tessmer, Wilson & Driscoll, 1989).
For instance: in computer-programming, examples of a concrete concept are the various data types represented as character, numeric, date.

2.3.2 Defined concept

Defined concepts have no tangible attributes, according to Newby & Stepich (1987). Unlike concrete concepts these concepts cannot be pointed to (Klausmeier & Sipple, 1980). Newby & Stepich (1987) in fact refer to them as abstract concepts. People often have to see the abstractness of concepts. These concepts are concepts by definition (Gagne, 1970; Tennyson & Boutwell, 1973; Gagne, 1985; Baine, 1986).

Defined concepts demonstrate the meaning of some particular class of objects, events or relations (Gagne & Briggs, 1979). Many natural classifications are based on these concepts according to Glass & Holyoak (1985). According to Cohen (1983) these concepts differ from concrete concepts along three dimensions: membership, tangibility, and complexity.

For instance: in computer-programming examples of defined (or abstract) concepts are the notions of read and write.

Defined concepts are somewhat poorly named. One of the problems surrounding defined concepts is the fact that classifying them as unencountered examples and non-examples, cannot be easily memorised as formal definitions; although an individual may acquire this capability while learning the definitions, according to Martin & Briggs (1986). Gagne (1985) provided the example of the concept of the relationship between a son or daughter, aunt and uncle, and must be shown in a way that follows the concept's definition. While the exact words do not have to be employed, these definitions must be clearly defined first. However, he acknowledged some abstract concepts do not have concrete counter parts: family, city, and transportation. These concepts must be understood by rule, or definition alone, according to Gagne (1985).

Aronson & Briggs (1983) pointed out that defined concepts often have concrete concepts as referents, and are classified using verbal descriptions or definitions. Defined concepts can depict a thing concept (Nelson, 1974), or a relational concept (Tversky, 1977; Ortony, 1979; Klausmeier, 1976), that classified objects or events (Gagne, 1985). Furthermore, Gagne (1985) suggested that a rule distinguishes a relation between two or more things. In fact, Landa (1983) described this knowledge about a rule as presenting itself in the form of propositions (Anderson, 1976) about an object.
2.3.3 Rule concept

Rule concepts represent the notion of meaningful information or declarative knowledge (Merrill & Tennyson, 1977; Gagne, 1985; Tennyson & Rasch, 1988). Gagne (1985) described these concepts as a verbal information skill. He suggested this type of concept is the lowest level of intellectual skill development.

In other words, rule concepts signify: (a) names or labels, or (b) single propositions or facts, or (c) are collections of propositions that are organized in a meaningful manner, by an individual (Gagne, 1985). A rule concept such as *key opens lock* is a statement about the relationship between one or more concepts (Baine, 1982). As with the case for defined concepts, it is essential to distinguish between being able to recite a rule and demonstrate the rule for appropriate examples (Martin & Briggs, 1986).

*For instance: knowing the rules associated with using numerics as character data types.*

However, as Haygood & Bourne (1965) explained, there were two problems associated with independent kinds of behaviour when paralleling the analysis of conceptual problems into rules and attributes. Firstly, the rule learning, in which the research participant attains or discovers the principle for partitioning the stimuli in a particular problem and acquiring the rule in general form so that it can be used in any problem. Secondly, the attribute identification, in which the subject attains or discovers the relevant attributes.

2.3.4 Process concept

Process concepts can be performed as well as understood (Klausmeier & Sipple, 1980). Because of this they suggested these concepts are a very different kind of concept for investigation within the field of concept learning research (Figure:2.3). They described these concepts as *science processes*, which are similar to Gagne's *defined concepts*. However, Klausmeier & Sipple (1980) gave the examples of: *observing*, *inferring* and *predicting*, which are typical science processes that can be performed, as well as understood in the same manner as the notions of the concrete concept of: *a tree*; or the defined concepts of: justice and *between*, as described by Gagne (1985).

According to Klausmeier & Sipple (1980), none of the concepts in previous concept learning research were identified as process concepts. They explained that the cognitive structure of an individual continually changes from birth onwards. To qualify this notion, they provided the example of the way human's perceive simple images of concrete objects like the sun sinking below the horizon, as well as learning abstract ideas such as wondering about the origins of the sun.
Process concepts can be described as the problem-solving discovery of two or more previously learned rules to solve an unfamiliar problem (Baine, 1982). This is a controversial issue, with no standard or widely agreed upon interpretation of just what constitutes problem-solving. For instance, one belief was that it involved a Gagne rule learning process plus the discovery of a new rule (Tennyson & Cocchiarella, 1986), while another view was to generate an individual’s own solution to a problem (Pask, 1984), and finally Martin & Briggs (1986) proposed that problem-solving involved simultaneously generating new content while observing many rules. Tennyson & Rasch (1988) described this intellectual process as a modelling process involving *procedural knowledge*, being an *integration-skill*, which is a *higher-order-thinking skill*. Furthermore, Tennyson, Elmore & Snyder (1991) suggested that it is the *procedural knowledge* applied in rational sets that maximise generalization and discrimination (Driscoll & Tessmer, 1985; Tessmer & Driscoll, 1986) exploiting (Tessmer, Calverly & Jonassen, 1989) the *declarative knowledge* (Merrill & Tennyson, 1977; Tennyson & Rasch, 1988) obtained from *rule concepts*. This is the lowest level of intellectual skill development (Gagne, 1985).

For instance: Figure 2.4 is an example of using a graphical approach as an innovative instructional strategy devised for this research to motivate interest in novice programmers.

Tessmer et al. (1989) concluded that it is the intellectual skill of *concept using* which should be married to the verbal information that makes concepts meaningful. They explained that a broader approach to concept learning can help bring our instructional models back into alignment with everyday teaching and learning.
Finally, they call for a continuing effort to be made by researchers, to study the effects of simulations, scenario-based instruction, through the selection of appropriate case studies to illustrate concepts for novice learners.

3. Instructional Strategies Under Constant Review

Instructional science seems to be in a state of constant change. The driving force appears to be the emerging trends relating to the capabilities of digital processing, according to McLellan (1996). Cooper (1993) aligned a series of paradigm shifts in instructional theory for designed instruction with available technologies of the time. From behaviourism, which employed low-level physical technology devices (Schoenfeld, 1993), to cognitivism which promotes technology based instruction systems to represent a learner's knowledge (Collins & Quillan, 1972). Constructivism, which relies on the experiences of the knower, requires building learning environments that facilitate knowledge construction by the learners (Tessmer & Jonassen, 1988). Herein lies the foundation for the serious debate, which has occupied the literature for a considerable time. For instance: see Merrill, Drake, Lacy, Pratt & the ID2 Research Group, 1996; Jonassen, Hennon, Ondrusek, Samouilova, Spaulding, Yeuh, Li, Nouri, DiRocco, & Birdwell, 1997).

Dinter (1998) attempted to clarify some issues on this debate. He maintained, to make any sense of the issues (Ertmer & Newby, 1993; Gruender, 1996; Greening, 1998), participants must know which methodological and epistemological considerations underpin each side of
the debate. On the one hand, the instructional strategies put forward from the proponents for efficiency and effectiveness, appear to make the assumption that there is no prior domain knowledge present in learners of new concepts. According to Perkins (1991), constructivists believe that learners generally know more in a passive sense than they ever master in realistic contexts of application. Although there have been warnings by Bransford, Franks, Vye & Sherwood (1989), as to the problems of relying on inert knowledge, the constructivists maintain the importance of it, as their central argument for designing instructional strategies to cater for individual differences. There is no serious attempt from either camp, however, to show how this can be achieved for either individuals or groups of learners.

3.1 Constructivist Approach to Concept Learning Strategies

Jonassen (1991) admitted constructivism is a relatively new concept in instructional systems. Although the literature revealed his valuable contribution to the field involving constructivist learning (Jonassen, Meyers & McKillop, 1996; Carr, Jonassen, Litzinger & Marra, 1998); his orientation to constructivism has obviously been evolving over time. For instance: Jonassen (1988) compared different instructional methods using interactive video, in order to test the prototype model of concept acquisition, and to assess the kinds of (mental) prototypes that learners develop. He used a typical Merrill et al. (1992) type of coordinate concept lesson, featuring the baroque, renaissance, impressionistic, and post-impressionistic styles, as close-in/non-example sets. Furthermore, he used an elaboration (Reigeluth, 1983) strategy, which Jonasssen suggested may in fact stimulate deeper processing, and enhance long term retention, and thereby produce an even more resistant performance.

3.2 Efficiency and Effectiveness of Automated Design

Tennyson & Cocchiarella's (1986) rationalistic approach to describing the learning process, viewed concept learning as a two-phase process: formation of conceptual knowledge, and development of procedural knowledge. Their view of concept teaching, was based on direct empirical validation from a programmatic line of instructional systems research.

*Conceptual knowledge* is formed in an individual's memory, and is more than just the storage of *declarative knowledge*; it also comprises a thorough understanding of a concept's operational structure, within itself, as well as between associated concepts (Tennyson & Cocchiarella, 1986). An individual develops *procedural knowledge* when using their *conceptual knowledge* to solve domain-specific problems. Furthermore, these two cognitive process phases interact when an individual exercises their *procedural*
knowledge during a problem solving exercise, which in turn elaborates their conceptual knowledge.

The second phase of their model dealt with the instructional design variables for teaching concepts. Tennyson & Cocchiarella (1986) explained that these instructional design variables are directly related to specific cognitive processes in concept learning. This component has three cognitive processing stages: to establish connections with necessary knowledge in memory; for the formation of conceptual knowledge, and the development of procedural knowledge. They suggested more research needed to be conducted to investigate ways to adjust the presentation strategies to account for development variables in a learner's nature, that account for possible differences in conceptual learning.

The instructional strategies devised for this study draw on the Tennyson & Cocchiarella model, to explain procedural knowledge levels as cognitive performance outcomes in the acquisition of abstract programming concepts.

Gulmans & Van den Berg (1992) designed a videodisc program based on the Tennyson & Cocchiarella model for concept learning. They tested the learning outcomes of variation of instances, the sequence of instances, and the effects of contrasts in the variable attributes of instances. Although referring to Merrill & Tennyson's (1977) concept learning research findings, the computer interface Gulmans & Van den Berg (1992) used for the experiment, did not provide the participants with clear operating instructions. Moreover, there appeared to be an apparent lack of theoretical evidence to support their user interface design.

3.3 Mental Constructs

Klausmeier (1992) used the term concept to refer to both an individual's mental construct and to the cultural meaning given to the concept name. He described the Cognitive Learning and Development (CLD) Theory, which defined the lowest entity as an item, to refer to an object, event, action, quality or relationship. Apparently, as an individual attains a given concept at successively higher levels of understanding, their mental constructs change. Klausmeier (1992) suggested that these fully developed mental constructs (Tennyson, 1992) enabled individuals to identify all examples and non-examples, as well as using the concept in an expert manner. Therefore, according to Klausmeier (1992), mental constructs were considered to be the building blocks of a person's cognitive structure, which can be thought of as the fundamental agents of all
thinking processes. Sadly, present instructional materials leave the learner to stumble through on a self-discovery (usually by disaster) learning tour (Merrill, 1994; 1998).

Because of this, some groups of people do not succeed! Effective instructional strategy must direct the learner to the general and critical attributes. Merrill et al. (1992) identified the concept’s attributes as providing the information with which the student must become cognitively engaged (Reigeluth, 1983).

The self-paced instructional booklets (see Volume: 3) devised for this research follow the instructional design doctrines. They have been used successfully with a broad range of higher education students, as innovative instructional tools.

Instructional strategies for the computerized learning environment must include both perceptive and non-perceptible attributes of the concept (Merrill, 1998), and the cultural meaning given to the concept name (Varela, Thompson & Rosch, 1995).

3.4 Relationship Modelling

The Bower, Black & Turner (1980) experiments investigated some psychological implications of Schank & Abelson’s (1977) Script Theory:

1) script generation
2) constituent structure of scripts
3) script recall
4) script recognition
5) script action reordering
6) script expectations and comprehension time
7) remembering deviations from scripts

Bower et al. (1980) used a familiar example of a script like eating in a restaurant or visiting a doctor, to show that script properties have culturally agreed upon attributes and instances. These activities have conventional roles, props, event-sequences, standard entering conditions, and standard outcomes (Bower et al., 1980). However, they also found that in remembering script-based texts, participants confused what was said, with what the script strongly implied. Furthermore, the participants preferred to learn event sequences that preserved the scriptal order; they were also best at recalling brief obstacles or distractions which caused a block or temporally suspended pursuit of the script goal; whereas irrelevant props or events were least recalled (Rosch & Mervis, 1975; Tversky, 1977; Merrill et al., 1992).
These theoretical views therefore support the use of a type of script knowledge in text, understanding, and recall. To capitalise on the culturally agreed attributes in familiar scripts, this research implemented a number of innovative examples as shown in Figure: 2.5.

There are six unresolved issues about Script Theory, according to Bower et al. (1980):

1) how to elicit script knowledge
2) level of detail that is recorded with each script
3) how to account for how special or novel contexts propagate throughout the script
4) at what level of abstraction the memory script is to be used
5) how to specify an induction algorithm
6) there is no clear way to deal with simultaneous execution of several scripts, which have strong interactions.

Finally, Bower, Black & Turner (1980) considered scripts as a powerful and potentially valuable theoretical approach. The unresolved issues and theoretical puzzles raised in their paper are not unique to Script Theory, but to any well-specified Schema Theory. They raised these issues to suggest the direction of future research.

Merrill et al.(1992) say that the cognitive processes involved in the concept acquisition process are called generalisation and discrimination. Generalisation occurs with a particular response in a stimulus situation, which was acquired in an earlier, but similar stimulus situation. When processing stimuli information presented by the new instance,
they attempt to make a precise "if .... then" inference. Discrimination occurs when a learner exhibits a particular response in one stimulus situation, but a different response in another stimulus situation, according to Merrill et al. (1992). For instance, when a generalisation from one instance to another does not produce the expected result, such as when an individual can acknowledge that a small dog, which is roughly similar in size and is also hairy, may in fact actually be a cat! Therefore, the first procedure in analysing a content area is to determine the relationships between concepts (Merrill et al., 1992).

4. Information Processing

There are a vast number of well respected theories of intelligence in the literature. Opinion is divided according to the personal orientation of the researcher. There are several researchers who proposed new and unsettling explanations about human information processing which completely refute a traditionalist approach (Jenkins, 1980; Baine, 1986; Bruner, 1990). There were several supporters of the notion that contextual considerations play a vital role in the information processing operations of the human mind (Jenkins, 1980). While there were others who propose a purely internal orientation (Scandura & Dolores, 1990); describing the human mind in terms of a closed processing system receiving continual input from the world around us. Artificial intelligence research is driving the focus of instructional science research to find the means to replicate the information processing of the human mind (Tennyson & Spector, 1998). However, there are a growing number of prominent researchers who no longer want to follow the traditional attempts to depict memory as a box in a flow diagram (Ortony, 1979).

Baddeley (1982) has written several books and many papers on human memory; it is a collection of interacting systems, which combine to store and subsequently retrieve information. It is our capacity to learn and remember, that has enabled us to develop tools, communication skills and technologies. Consequently, it is through this interaction of communication with technology, that humans now have an even greater capacity to store and retrieve vast quantities of information. The progression of our ability to communicate through writing, filmmaking and indeed television can, thus be regarded as an extension of the human memory.

Trying to categorize human memory becomes too theoretical according to Baddeley (1982); there are no true answers, only interpretations of available evidence. In organizing information mentally, however, one of the most common techniques humans draw on is
their visual imagery ability. He demonstrated the effective use of peg words (Reigeluth, 1983-a), to recall sequences of unrelated items in an appropriate order.

Given the abstract nature of most programming concepts, it is helpful to know where instances exist of previous research dealing with the issues of instructional strategies for human/computer interaction. Therefore, the following sub-sections discuss:

- Cognition and instructional format
- Process-oriented learning resources
- Cognitive style
- Visual perception
- Visual literacy

4.1 Cognition and Instructional Format

Most of the past research on memory was highly controlled, with results reflecting the contrived experimental laboratory conditions (Baine, 1986). In reviewing memory models and research, he warned against generalising laboratory findings from past research on memory to the natural environment, unless the exact nature of the experimental procedures are known. Mnemonic strategies were practical techniques which have the potential to make information more memorable and easier to retrieve (Baine, 1986). Note, for example, he drew on other well known research such as Rosch's (1978) principle of cognitive economy, in identifying labelling, visual imagery, and maintenance rehearsal as mnemonic strategies.

In relation to visual imagery research, Baine (1986) referred to numerous studies, which involved children. Most of these studies directed the visual imagery behaviours, with participants being instructed to create their own images. Thompson & Riding (1990) believed such instructions to be an unsuccessful type of self-reporting test.

This research concentrates on an adult population, therefore it was critical to search the literature for evidence to explain how cognition may change over time.

As the cognitive approach tackles the great complexities of learning processes (Winn, 1980-a; Winn, 1982-a), cognitive theories may offer a more comprehensive account of learning. Because of the extent to which cognitive theories extend into human learning, this in turn permits a more complete repertoire of instructional strategies that researchers can develop for designers to use and refine. Furthermore, he suggested that the cognitive approach offers the opportunity for research and practice to move closer together, given that research findings
often take some time to filter through as practice. This is due once again, to the complex nature of learning (Winn, 1982-a).

Designers on the one hand need to think and design instruction in terms of cognitive processes, rather than in terms of overt learner performance (Winn, 1982-a). This means they will need to be aware of cognitive research. While on the other hand, researchers need to deal with learners in natural settings; they need to work more closely with designers. This is because the cognitive approach takes into account things like existing knowledge and interaction with the learning environment, permitting a more comprehensive assessment of learning in the real world (Winn, 1981).

Furthermore, (Winn, 1982-a) speculated on which aspect of the learning processes provide the most influence: instructional strategy or mental skill; knowledge of task (Ausburn & Ausburn, 1978); the information presentation form, or general ability (Winn, 1982-b).

However he postulated that a factor such as knowledge of task, is so important in the learning process, that it overshadowed other aspects of instructional strategies, to the extent that telling learners anything more elaborate than what is expected of them would be a waste of time.

Tennyson & Rasch (1988) described a Learning Environment Model (LEM), as an instructional design model to link cognitive processes and objectives to specific instructional methods. They proposed this model to focus on the planning of a learning environment to encourage students not only to acquire knowledge, but also to improve their cognitive ability to extend their knowledge acquisition skills. They expanded on earlier research, in which Tennyson & Cocchiarella (1986) suggested that the structuring of concept variables can be divided into two separate learning conditions. The first learning condition was a relational structure within a domain of information; the second was the attribute characteristic, which defines the concept's attribute characteristics, within a schema, along a constant/variable continuum. They suggested that 55% of a learning environment needs to be planned to encourage acquisition of the student's knowledge base (storage to memory), while the remaining 45% of the learning time, needs to be allocated to employment and improvement of the student's knowledge base (retrieval from memory).
The following topics summarise related research dealing with the complex issues relating to cognition and learning, including:

- Cognitive style construct
- Cognitive strategies
- Hemispheric specialisation
- Nature of cognitive representation
- Cognitive economy and perceived world structure
- Knowledge representation frameworks
- Perceptual learning
- Beyond literal similarity
- Symbol systems

4.1.1 Cognitive style construct

A valuable contribution has been made to enable comprehension of the differences in learning and behaviour as a complex human interaction. Therefore according to Riding & Rayner (1998:1):

"The concept of style is an idea used frequently in everyday language. The concept has been used more technically in the psychological study of individual differences in learning and behaviour. In this respect it is used as a 'construct'. A construct is a psychological idea or notion. Examples of constructs are intelligence, extraversion and neuroticism."

4.1.2 Cognitive strategies

The context of this learning domain has undergone considerable review by instructional design specialists. For instance: Gagne (1985), described five categories of learning capabilities:

1) intellectual skills
2) verbal information
3) cognitive strategies
4) motor skills
5) attitudes
For the full description of the cognitive strategies adopted for this research, see Chapter Four: Conditions-of-the-Learner (topic 2.1.2 Gagne's capability categories).

He suggested that the verbal (or declarative) learning outcome is strictly low-level; students can repeat back exactly what has been presented without regard to any higher-level learning outcome. He described higher-level learning outcomes as cognitive strategies; quite separately from the lower-level verbal learning strategies. However, the declarative learning domain has now been subsumed within more recent cognitive processing theories (Perkins & Salomon, 1989; Scandura & Dolores, 1990). More recently Merrill & the ID2 Research Group (1996) described a computerized courseware authoring system, capable of presenting knowledge objects that are able to support the parts-of, kinds-of, how-to, and what happens, as types of knowledge elements.

This research describes and measures the cognitive performance in terms of instructional outcomes, which draw on the verbal information, intellectual skills and cognitive strategies as described herein.

Cognitive strategy activators were described by Reigeluth (1983-a); an analogy should be described before the new content is taught, with references made to the analogy during the lesson. They can be activated in a manner that forces the learner to adopt an instructional strategy as either embedded or detached activators. Reigeluth emphasised that relating new knowledge to prior knowledge is only one of several important learning concerns of instructional theories and models. Other kinds of learning concerns are:

1) motivating the learner
2) focusing the learner's attention on salient features of the learning content (Crouse & Idstein, 1972)
3) facilitating dual encoding (see Paivio, 1971)
4) facilitating an appropriate level of cognitive processing needed to achieve the desired level of outcome
5) providing other kinds of instructional support, like shaping and systematic review

This work aligns with the supplantation strategies described by Ausburn & Ausburn (1978).
The self-paced instruction booklets in this research were designed to draw on these principles (see Volume: 3). They have proven to be successful in motivating the novice learners to achieve high-level procedural knowledge outcomes necessary for writing algorithms for computer programs.

4.1.3 Hemispheric specialisation

No single mechanism is critically responsible for the performance of cognitive functions or memory (Lindsay & Norman, 1977). They suggested the left hemisphere usually contains the information necessary for processing language symbols. While the right side is incapable of language production. It is capable however, of language recognition (Lindsay & Norman, 1977).

They described the differences between left and right propensities for language recognition and comprehension. Left is usually associated with specialized ability for the performance of analytical or logical thinking; whereas the right half (for most people) provides non-analytical continuous, or synthetic modes of thought and is often regarded as non-scientific, prone to rhythmic, artistic, and creative in style. Their research findings from studies of the two hemispheres of the brain, showed minute differences in the normal person, and could only be observed under special conditions, with the only solid scientific evidence from performance of simple processing tasks. There was simply not enough evidence to test the hypothesis that two hemispheres control radically different styles of thought, and that some people may be dominated by one hemisphere, producing different thought patterns from other people. They suggested these hypotheses are sheer speculation.

However, more recently Kosslyn (1987; 1988) and Kosslyn, Malijkovic, Zhamilton, Horwitx & Thompson (1995) have contributed valuable insights to the way humans process visual mental images, using either side of the brain.

4.1.4 Nature of cognitive representation

Rosch (1975-a) was concerned with investigating whether cognitive representations were formed as concrete imagery, or conversely, whether individuals' thought processes are actually abstract and imageless. Furthermore, her work pursued the broader question of whether all meanings have common abstract forms notwithstanding their context, or whether meanings are represented in a number of ways. For instance: with verbal instructional materials and for picture representations.
It was necessary to establish the central theoretical view relating to cognitive representation, for the design of the instructional strategies adopted for this research.

In contrast with previously held views on the nature of natural categories, Rosch & Mervis (1975) argued their work on family resemblance (which is now very well known), offered an alternative to previous research which proposed a logical representation to reflect the analog (all-or-nothing) nature of some natural categories.

Artificial categories were under investigation by Rosch & Mervis, because they believed it was possible to introduce attribute structures, as independent variables, in a controlled environment, with the development of prototypes studied as the dependent variable. They viewed this research as important, because they were able to demonstrate a new link (Tversky, 1977) between adult and children's modes of categorization. Cognitive family resemblances were shown by them to be a form of complex grouping, which appeared to be one of the structural principles utilized in a superordinate structure (Merrill, 1994) by adults.

Rosch (1978) explained that the issues of categorization (Rosch, Mervis, Gray, Johnson & Boyes-Braem, 1976) were often misunderstood. Her research was concerned with cultural categories, coded by that culture at a particular point of time. Furthermore, she pointed out that the principles of categorization were not meant to represent a theory of how the young develop categories within a culture; nor indeed represent a model of how adults process categories.

4.1.5 Cognitive economy and perceived world structure

Rosch (1978) proposed two general principles to provide the foundation for human cognitive categorization systems. *Her first principle*, called the cognitive economy; related to the automatic way humans conserve their cognitive energies. It was seen as a method, which balances our need to discriminate between the infinite number of things we wish to know, and those things of lesser importance. *Her second principle*, related to the highly correlational relationships which occur in the material objects of the world. Rosch defined this principle of categorization, as the perceived world structure. However she warned, that it must not isolate the knower from the notion of the perceived world. In addition to this, Rosch explained the influence of the culture at any particular point in time determines the human category system.

However, research into the role of objects in events was reported by Rosch to be in its infancy. She revealed observations relating to a pilot study designed by Elizabeth Kreusi. Unfortunately, this work has not been formally reported. Rosch revealed that initial results
from this new research were showing similar patterns to earlier work, involving superordinate category translation into basic-level objects and actions.

4.1.6 Knowledge representation frameworks

Baddeley (1982) suggested that mnemonics based on imagery, implements the notion of cognitive economy (Rosch, 1978). He described a computer program called *The Teachable Language Comprehender*, devised to represent knowledge. Quillian (1969) developed the program for the purpose of understanding language. The logic around which this system was developed, resembles the Rosch (1975) cognitive representations of semantic categories, and Merrill's (1994) *parts-of* taxonomy. Unfortunately, the program fails to fully represent human cognition in terms of our decision-making ability. In fact, this was a good example of a failure to understand and represent the nature of natural categories (Rosch & Mervis, 1975).

The *programming metaphors* (as knowledge representation frameworks) designed for this research tests out Script Theory. Using everyday examples of events individuals deal with on a daily basis as scripts to motivate a novice learner.

A script was described as an elaborate causal chain, which provides world knowledge about an often experienced situation, normally associated as definitions of certain situational nouns (Schank, 1975). Scripts have been proposed by Minsky (1975). However, the scripts referred to by Schank (1975), represent only a small subset of the concept used by others.

Minsky (1975) suggested a framework for representing knowledge using theories of intelligence that propose to substructure knowledge into *microworlds*, *problem-spaces*, or *linguistic objects* and to move away from the traditional attempts by behaviouristic psychologists and by logic-oriented students of artificial intelligence. They are attempts to represent knowledge as collections of separate, simple fragments (Minsky, 1975). His theory involved the notion that humans select from their memory a *frame structure* that consists of separate nodes and relations all linked into a hierarchy system. The top level is fixed and represents the things that are always true about a supposed situation (Minsky, 1975).

Bobrow & Norman (1975) proposed an opposite view. Most of the proposals for the representation of information within memory, can be viewed as variants of list structures, or semantic network structures, they call *schemata*. Their postulation included an amalgamation of the computing principles from the literature on:
1) semantic networks
2) actors
3) frames

4.1.7 Perceptual learning

In so far as implications exist for the psychological fields of imagery and perception, Rosch (1978) suggested that the basic-level objects offer the most inclusive categories by which humans can form mental images, drawing on human perception of the world at this level of abstraction. Objects are first seen or recognized as basic category members, and indeed, need further cognitive processing to be identified as higher-order categories (Rosch, 1978). She argued against performing experiments to distinguish which principle determines prototype formation and category processing as an artificial exercise. There is a highly negative correlation effect for attributes belonging to members of contrasting categories. Noticing these negatively correlated attributes may be part of the way humans actually structure real-world categories. However, she conceded these research findings do leave many unanswered questions. Prototypes do not actually represent any particular model of processes, representation, or learning. Moreover, the term prototype was often used when researchers really mean judgements of degree of prototypicality (Rosch, 1978). A more correct usage was, therefore, simply as a convenient grammatical fiction.

There were two issues that were problematic for her principles of categorization: They relate to:

1) the relation of context of basic-level objects and categorization
2) assumptions made about the perceived nature of the attributes of real-world objects which form the premise that there is structure in the world

However, Tversky (1977) referred to the work of Rosch & Mervis (1975), by suggesting the importance of prototypicality or representativeness in perceptual learning. He contrasted the view that natural categories were definable by conjunction of critical features with the philosophical argument from Wittgenstein (1963) (Tversky, 1977:348, with the term abstract concepts added for this thesis):

"Several natural categories (abstract concepts) do not have any attribute that is shared by all their members, and by them alone"

Jenkins (1980) explained he could produce a contrasting view of human memory theory. He argued that when we talk of memory, contextualism involves consideration for what the student believed and knows. He described the importance of personal belief, when
distinguishing memory from the other higher mental processes. Furthermore, he maintained, that apart from the belief that the construction of the mind is attributed to an individual's past, there was nothing to set memory apart from perception, imagination, comparison, and reasoning.

This explanation unsettled the earlier postulations by memory researchers, because it attests (Jenkins, 1980:308):

"memory is not a box in a flow diagram"

A further point was considered as unsettling, because of the demand for an understanding of all of the higher mental processes at once. He proposed that to study memory without studying perception, was to invite disaster. Similarly, to study memory without studying interference, and to study memory without studying language, etc, was dangerous. However, he maintained that contextualism avoided these pitfalls, by relating one's laboratory problems to the ecologically valid problems of everyday life.

### 4.1.8 Beyond literal similarity

Metaphors according to Earle (1994:35):

"condense a multifarious collection of cognitive and emotional experiences into a single, vivid communication"

Tversky (1977) suggested that similes and metaphors are usually understandable despite their novelty and non-literal nature. The connotative richness of meaning accounts for human's ability to interpret metaphors without specific prior learning (Tversky, 1977). He explained that people appear to interpret similes by scanning the feature space and selecting the features of the referent (Merrill, 1994) that are applicable to the subject. Tversky suggested that the characteristics of a good metaphor were the contrast between the prior, literal interpretation, and the posterior, metaphoric interpretation. He maintained that metaphors that are too transparent are uninteresting. Furthermore, he proposed that obscure metaphors are uninterpretable; good metaphors are like good detective stories (Tversky, 1977:349):

"The solution should not be apparent in advance to maintain the reader's interest, yet it should seem plausible after the fact to maintain coherence of the story ................. similes and metaphors are essential ingredients of creative verbal expression ". 
Ortony (1979) expanded Tversky's work on metaphors and similes beyond literal similarity. He proposed that a complete account of similarity needs also to be sensitive to non-literalness, or metaphoricity, an aspect of similarity statements that is most evident in similes but that actually underlies metaphorical language in general. He advanced theoretical arguments in support of the claim that metaphoricity can be represented in terms of the relative degrees of salience of matching (or matchable) attributes of the two terms in a comparison. For instance: billboards are like placards, cigarettes are like time bombs, and encyclopedias are gold mines. He proposed an account of similarity that offers the prospect of determining just how similarity, analogy, and metaphoricity relate to one another (Ortony, 1979:179):

"It should be reiterated that metaphoricity is a characteristic of similarity statements (and judgments). This observation alone could have important consequences for the way in which similarity is conceptualized and for the kind of empirical research that is undertaken in the area of metaphor ................. much of cognition depends on the recognition of metaphorical relations - on going beyond literal similarity."

Earle (1994) suggested that while metaphors help to explain a process or provide meaning for a relationship, they are limited by the ineffectiveness of imagery to fully render detailed descriptions of that process or relationship.

The interactive effect of cognitive style and instructional strategies (textual and graphical metaphors) will be measured in this research, breaking new ground for the management of cognitive performance outcomes.

4.1.9 Symbol systems

Symbols constitute the most basic form of character or coding element humans use to communicate with, and as such must conform to cultural rules and conventions. When this occurs, Salomon (1979) proposed symbol schemes formed from symbols. He described how symbols have the potential to develop into a complicated system, when correlated with a field of reference. This field of reference then becomes compliant with, or is denoted by, the symbol scheme.

For instance: the computer programming syntax rules are a field of reference for writing computer programs.
Like Salomon (1979), Bruner (1986) has examined the human imagination, and acknowledged the work of Goodman, who advocated that minds become specialized to cope more easily with verbal, mathematical, or spatial forms of worldly things. According to Bruner, Goodman's proposals have clarified the differences between art and science. Both domains must share common cognitive functioning in so far as processing symbols, performing analysis, and classification of symbol systems is concerned (Goodman, 1968). The concept of mind can now be specified as an instrument for producing worlds rather than the previously held view of merely identifying its properties.

Goodman's (1968) theory on symbol-systems was most stringent, consistent, and clear. His use of the term correlation, to describe the relationship between a symbol system and its field of reference, was imaginative (Salomon, 1979).

Baine (1986) appeared to use the term loci mnemonic, in the same manner as the Rosch et al. (1976) description of the basic level of classification. Furthermore, the description he gave for the imagined interaction between each item in a shopping list, and each of the loci used by research participant, paralleled the examples of field of reference compliance with symbol schemes, described by Goodman (Salomon, 1979).

4.1.10 Summary of cognition and instructional format

This ends the epistemological argument for information processing taken by this research. A number of well-respected theories of intelligence have been presented, reflecting the personal orientation of the researcher. Technology drives one group of researchers to pursue the notion of creating artificial intelligence, as a means to replicate the information processing capabilities of the human mind. Conversely, a number of prominent researchers have changed their opinion from the traditional attempts to depict memory as a segmented entity represented in a systems-like structure chart. The literature revealed several supporters of the notion that external considerations from the environment affect the information processing operations of the human mind. While there were others who proposed a purely internal orientation; describing the human mind in a mechanistic manner as a closed processing system, receiving continual input from the world around us, as isolated sensory data which is processed in a highly organized fashion.

Finally, to complete the spectrum of views; there were several researchers who now propose unsettling explanations (about human information processing), which completely refute the traditionalist approach.
4.2 Process-oriented learning resources

To anchor the research outcomes for this thesis, a more current stance is needed. This conceptual framework now describes how technological advances are affecting course delivery methods. McDermott Hannafin (1993) described one method for improving undergraduate education, in response to the traditional methods, which have in the past been passive, and overly prescriptive, concentrating on discrete and disconnected measures of student performance.

The instructional method believed to improve student learning was the design of process-oriented learning resources (McDermott Hannafin, 1993:77) as:

"teaching and learning activities which engage students cognitively in analyzing and transforming information"

Process-oriented resources promote cognitive engagement; by this she means the learners are actively drawing on their cognitive functions and operations to orient themselves to the new information. While thus engaged, they are able to retrieve related material from their long-term memory; thereby constructing and transforming information, which in turn becomes encoded into new understandings which can then be stored into their long-term memory (McDermott Hannifin, 1993). Particularly, when process-oriented outcomes are expected, teaching methods should reflect the critical thinking, reasoning or problem solving that is required as a learning outcome.

When learners are given a cookbook of steps to follow for solving particular types of problems, learners would rather pay more attention to the application of the steps, than to the understanding required for applying the steps to achieving a suitable solution. The danger may be that they only experience their learning at a surface level, without ever developing the necessary insight to solve problems in general (McDermott Hannifin, 1993).

The instructional content for this research is given in the light of the McDermott Hannifin view. The instructional material provides opportunities for the novice learner to read, and compare their problem solving ability with provided solutions (Figure:2.6).

When the facilitator uses instructional strategies in which they verbalize, describe and model their thinking processes, the learners are able to model the facilitator's problem solving strategies, as well as the reasoning processes underlying the problem solving strategies (McDermott Hannifin, 1993).
How to proceed?

The following instructional strategy requires you to do four things:

1) Read all the material carefully before proceeding to the practical work at the end of this booklet
2) Read the practice examples starting on page 8
3) Complete the two exercises starting on page 10
4) Complete Questionnaire-2, indicating when you are ready to do this by raising your hand

4.3 Cognitive Style

There are a number of ways to measure cognitive style (Riding & Cheema, 1991). However, Riding & Rayner (1998) suggested that combining the issues relating to cognitive style and learning strategies is new. Williams (1996) explored the relationship between user cognitive style and user satisfaction with an Information System. He used the Myer-Briggs Type Indicator (MBTI) (Myers & McCaulley, 1985) to identify cognitive style in his exploratory study.

This research draws on the work of Riding & Cheema (1991) to operationalize one of the independent variables (cognitive style and instructional format).

The next discussion provides the justification for drawing on this work, focussing on the following topics:

- Hemispheric specialisation
- Measuring visual/verbal propensity
- Cognitive style measurement
- Representation of information during thinking: Verbal/Imagery
- Mode of processing information: Wholist/Analytic
4.3.1 Hemispheric specialisation

Riding, Glass & Douglas (1993) explored categories of individual differences in brain functioning. They suggested that hemispheric specialisation was usually associated with the right hemisphere being the location of the *visuo-spatial*, and the left side being the *verbal*; although evidence for this has been sometimes conflicting (Jenkins, 1980). This was not surprising as attention has not been paid to individual differences in cognitive style, as research participants of different styles will use different processes when doing the same cognitive task (Ausburn & Ausburn, 1978). However, Riding et al. (1993) believed that where possible, individuals would represent and process information in their habitual modes. Consequently, *Verbalizers* will translate pictorial information into words, whenever possible. Furthermore (Riding et al., 1993:276):

"The effect of this will be that, while verbal information will result in predominantly left hemisphere activity in Verbalisers, it may also produce right hemisphere activity in Imagers where the material allows this".

Howell (1972) compared Lowenfeld's (1939) *Haptic-Visual* types, with Witkin's (Witkin, Dyke, Patterson, Goodman & Kemp, 1962) *Field-Dependent-Independent* perceptual types, through physiological data provided by an Electroencephalogram (EEG). Howell hypothesized, that *visual* types would correlate positively with the *Field-Independent* types, and the *Haptic* types would correlate positively with the *Field-Dependent* types, on the EEG data. Because there were discrepancies between the literature and Lowenfeld's findings, he recommended that further research be conducted to explore the issue of relating *alpha* types to visual imagery and *Haptic-Visual, Field-Dependent/Independent* types. Furthermore, Lowenfeld's *Haptic-Visual* Theory needs to be re-examined, due to the apparent weaknesses Howell (1972) found in the methodology used for that research. Howell called for educators to be cognisant and responsive to perceptual differences amongst students, so that teaching methodology and theory can be more in line with the individual differences of the students.

4.3.2 Measuring visual/verbal propensity

Paivio's (1971) Dual-Coding Theory is well known (Riding & Rayner, 1998; Kosslyn, Behrmann & Jeannerod, 1995). It described the human memory's capacity to deal with visual images, and verbal processes, as parallel and sequential information systems. Riding (and his collaborators') research has contributed to the field of cognitive/learning style research spanning two decades (Riding & Taylor, 1976).
Earlier researchers have proposed three general approaches to measuring imagery performance:

1) introspective method, the Betts (1909) vividness questionnaire
2) to equate imagery ability with spatial ability and test the latter by Barratt (1953)
3) measures the time research participants take to generate images (Moore, 1915; Paivio, 1966).

Riding & Taylor (1976) have added a fourth method. This alternative method to measuring imagery performance was related more to the type of memory coding employed by the learner, when analysing prose material. They were assuming that some children used a predominantly imaginal code, while others store new information in a verbal form. They thought it might be possible to distinguish between these children, on the basis of the latency of their response to a question about the prose material. Those who used imaginal coding translate what they hear into a visualization of the scene, and consequently are able to reply very quickly with the colour of the door, which they can see, according to Riding & Taylor (1976). They posed a question relating to the coding test, based on the prose reception task, which was more related to real comprehension than the image generation test. They showed that while most participants can probably code either imaginally or verbally, they tend to predominate in one mode. Therefore, when put on the spot, Riding & Taylor (1976) suggested that an individual might resort to familiar cognitive means to make sense of things. This concurs with Pask’s (1984) notion of private/public concepts, and may result in stressing an imaginal thinker when faced with producing a quick response.

4.3.3 Cognitive style measurement

Borg & Riding (1993) discussed the two basic dimensions of cognitive style from Riding & Cheema (1991):

- **Wholist-Analytic (W:A)** describes whether an individual tends to process information in wholes or parts
- **Verbal-Imagery (V:I)** describes whether an individual is inclined to represent information verbally or in images during thinking.
Riding, Buckle, Thompson & Hagger (1989) investigated the development of a short, computer-presented test of *Verbal-Imagery cognitive style*, capable of incorporation into a computer-based training (CBT) package. Their test consisted of pairs of words presented on the computer screen. They suggested that *Verbalizers* will respond more quickly to word pairs that could be answered through verbal associations, while *Imagers* respond more quickly to those word pairs, which require the use of mental pictures. In the computer presented test, the individual has to decide:

"whether the relationship presented between the first word and the second, belonged to the same category".

The test employed the following examples:

1) the same colour as *snow-flour*
2) the same shape as *button-plate*, etc.

According to Riding et al. (1989:395 with the addition of the term *word-pair* for this thesis):

"It was anticipated that imagers would respond more quickly to the same colour and same shape categories because the objects could be readily represented as mental pictures, and the information for the comparison could be obtained directly and rapidly from these images. In the case of the other two (word-pair) categories, the verbalizers have a shorter response time because the association is verbal in nature and cannot be represented in visual form"

This computer test determines a person's relative *Verbal-Imagery style* by comparing their speed on the *verbal* sections with that on the *imagery* sections. To do this, ratios are taken of their response time on one of the *verbal* sections, to that on one of the *imagery* sections. For instance: the ratio of response time on the test section Category-4, which is *verbal*, to that on Category-1, which is *imagery*, would be high if a person were faster on -1 than on -4. Consequently, the computer program calculates that person as an *Imager*. If the ratio is low, the individual is faster on -4, which is *verbal*, than on -1, and therefore, is shown as a *Verbalizer* (Riding et al., 1989).

In another experiment, Thompson & Riding (1990) utilized the same computer-presented program, as the treatment for their experiment conducted in a senior-primary level classroom, involving 108 participants with instruction on shears and rotations, and how these transformations could be used to validate the Pythagorean Theorem.
4.3.4 Mode of processing information: Wholist-Analytic (W:A)

Riding & Mathais (1991) suggested a second fundamental cognitive dimension is the Wholist-Analytic style. Elsewhere it is referred to as field dependence-independence (Witkin, 1950). Subsequent research shows that this style is also linked to cognitive performance, and it was felt that for education and training it was more meaningful to use the term Wholist rather than field dependent, since a business trainee views that material in wholes; and Analytic rather than field independent since in this case the individual parts of the information are separated out (Riding & Mathias, 1991:386). They explained however, that Riding & Banner (1986) found an interaction between Wholist-Analytic style and Verbal-Imagery style, in their effect on performance on second language learning; such that on some tasks, Wholist participants were superior to Analytic.

(Riding, 1991) explained this test differs because it (Riding & Mathias (1991:387):

"positively measures the wholist tendency and does not simply assume that if a person does poorly on a disembedding task that they are field dependent. This overcomes a major objection to the notion of field independence being a learning style raised by those who have argued that since generally field independents are superior to field dependents, it is simply a correlate of intelligence or general ability. Secondly, it compares a person's relative performance on the two halves of the continuum. Thirdly, by using computer presentation, it allows more sensitive timing of the task"

In terms of the Wholist-Analytic, Verbal-Imagery styles, and overall cognitive ability, Riding & Mathias (1991:390) suggested that there is a lack of interaction between the styles and content of the testing batteries because:

"(a) the instructions for each of them was spoken and required fairly extensive verbal comprehension, and (b) while the non-verbal battery was not in text form the type of task would not especially favour imagers as a whole."

Whereas, the performance by Analytics, they suggested, improved across the three batteries from the verbal to the non-verbal. Riding & Sadler-Smith (1992) argued that the mechanisms underlying the two cognitive style dimensions are independent of one another, and can be employed separately. They suggested a further point, that most tasks will require both structure and representation. In view of this, they proposed that individuals would develop cognitive strategies to press into service, for performing
tasks, in cases where their own cognitive style is inappropriate; rather like the supplantation techniques described earlier by Ausburn & Ausburn (1978).

4.3.5 Representation of information during thinking: Verbal-Imagery (V:I)

Riding & Calvey (1981) extended and refined the code test of Verbal-Imagery performance, to include positive assessment of verbal performance, replicating the findings of Riding & Taylor (1976) with older children, using a wider range of prose passages as learning material. They assessed verbal coding, as well as imaginal coding, by adding a set of questions that would be likely to test the efficiency and use of verbal representation (Kosslyn & Pomerantz, 1977).

Furthermore, Riding & Calvey (1981:64) revealed that:

"a reasonable conclusion would appear to be that, while all subjects use a dual representation in processing prose details, many of them are either much more proficient at, or prefer, one mode than the other. When the material does not match their characteristic mode, they either have to try to translate it into other preferred mode with a consequent use of processing time and perhaps some loss of information, or use the mode in which they perform less well"

They concluded that the representation mode appears to be a learning style, rather than a reflection of overall intelligence, suggesting that the Verbal-Imagery code test appears to differentiate between individuals, in terms of their performance on the immediate recall of prose materials that differ in their style with respect to the amount of visual description and semantic complexity. These findings are consistent with the view that there is a Verbalizer-Imager learning style continuum.

4.3.6 Desirable cognitive styles

Riding & Sadler-Smith (1992) found an interaction of the W:A dimension, and structure of learning material, in their effect upon learning performance. They hypothesised that W:A and presentation order would interact in their effect on learning performance. In view of the overall performance expected from an interaction of instructional format and each cognitive style, Riding & Caine (1993) reported that the Analytic-Verbalisers lack any facility for obtaining a whole view necessary for integrating the different aspects of a particular subject.
They proposed more specifically, in relation to the performance on their subject matter, that there were two factors affecting performance:

1) the extent to which the subject matter or learning content requires a whole, or a part view, and the degree to which this requirement is matched by the individual's cognitive style.

2) the degree to which the subject matter has a verbal or pictorial cognitive emphasis, and the extent to which this requirement is matched by the learner's cognitive style.

Furthermore, Riding & Caine (1993) were able to show that for a learning content involving mathematics, there was a similar performance expectation; except for the Intermediate(W:A)-Imagers and the Analytic-Verbalisers who did relatively less well.

Moreover, Riding & Mathias (1991) revealed that the Wholist-Verbalisers performed well, suggesting it was likely that verbal representation has the characteristics of both semantic coding, and a degree of analytic facility, while imagery representation has both pictorial quality and its associated wholeness.

Douglas & Riding (1993) used the term advance organisers (Reigeluth,1983-a; Di Vesta,1988), in a manner that suggested an Ausubel-like usage. However, they did not refer to the instructional design research. Bransford & Johnson (1972) demonstrated that merely having prior knowledge is not adequate; it must become an activated semantic context. They suggested that the presence of advance organisers may only be appropriate for Wholists. Their results also made it clear that the inclusion of a title before a passage, does not provide the necessary information, for an Analytic individual to acquire an adequate view of the whole. They proposed that consideration should be given for other instructional techniques, which may address this problem, suggesting a need for investigations into an instructional strategy such as the supplantation technique (Ausburn & Ausburn,1978).

4.4 Visual Perception

There were enormous flaws in the visual imagery instrumentation (Thompson, 1990).

According to Palmer (1977:471) it was clear that:

"cognitive theories of perception and imagery must deal with organizational structure and its role in processing more precisely than they have in the past"
Ritchey (1980) has conducted research using both adults and children; providing evidence that pictures and words activate a common abstract representation in memory (Rosinski, Pellegrino, & Siegel, 1977). However, there is a considerable body of evidence, which shows differences in recall for pictures and words in adults (Paivio & Csapo, 1973; Sampson, 1970).

Ritchey (1980) suggested that a meaning representation of an abstract nature of an uncommon item, makes up what will be referred to as an individual's extended representation. Not all of these representations are activated for understanding, only the core definition. Furthermore, he postulates (Ritchey, 1980:462):

"while the core definition would be activated any time the lexical item is accessed, activation of the extended representation would be specific to situation and context. ...................... if a picture of a camel is presented instead of a word, then the additional information a picture contains about the physical detail of the object may again cause a more elaborate activation of the meaning representation"

It was suggested by Ritchey (1980), that memory activations within the semantic domain would vary on two dimensions, both between-meaning representations and within-meaning representations. Pictorial stimuli, because of the additional information they contain about the physical properties of an object, would tend to give rise to more extensive activations within-meaning representations than their verbal counterparts.

Holliday's block-word diagrams (previously discussed in section 1.4 of this chapter), showed relationships between concepts dealing with the processes of a food chain (hawks eat snakes, snakes eat mice), and were shown by arrows. Class inclusion relationships (mice are herbivores, herbivores are consumers), were shown by placing appropriate concepts in the same rectangle, and then by shading it (Winn, 1980-b). Placing concepts together in one square, helps the learning of generalizations, because it facilitates the perception of similarities between them (Winn (1980-b). While at the same time, placing each concept in its own square, assists the novice learner to discriminate between concepts, as it facilitates the perception of differences. The ordering of the squares and the concepts within them sequentially, or by means of arrows, contributes to the formation of associations and chains, by helping the novice learner perceive logical, causal, and sequential relationships. This was more support for Ausburn & Ausburn's (1978) notions of supplantation techniques.

The success of diagrams used to stimulate learning, rests on their ability to structure concepts, and to emphasize some and de-emphasize other relationships among them
Winn (1980-b). Winn (1982-a) gave a comprehensive review of the current cognitive theories on visualization in learning and instruction, dividing his comments into three areas for discussion:

1) taking a cognitive approach to visual learning and instruction
2) guidelines for three types of instructional strategy
3) cognitive research directions that instructional design research should implement from the cognitive psychology research findings.

Rieber (1995) used visualization in an historical review of research literature. On the one hand, visualization was synonymous to imagery; he defined visualization as the representations of information consisting of spatial, nonarbitrary (picture-like qualities, resembling actual objects or events), and continuous (like an all-in-oneness quality) characteristics (Paivio, 1990). On the other hand, verbalization included both internal (mental imagery) and external representations (real objects, printed pictures and graphs, video, film, animation).

4.5 Visual Literacy

The use of this term also differs according to the researcher's discipline. Levie & Lentz (1982) explained what might be called by some as an information-analysis approach to this type of research. They were able to show there were possible relationships between the information in a text passage and in the illustrations. They suggested it is possible at times to experience an information overlap between the text and relevant illustrations.

Researchers in this area need to clearly identify which kind of information is being tested, by raising such questions as (Levie & Lentz, 1982:196):

"Does the test measure the learning of illustrated text information only, nonillustrated text information only, or some combination of these? What role does picture-only information play in the test? When researchers control these relationships, greater clarity about the effects of text illustrations is possible."

Since the end of the nineteenth century, there has been a growing awareness of thinking styles. However, research has been unable to measure thinking style in terms of educationally significant correlates (Thompson, 1990).
The apparent unsuccessful research was due to the self-report nature of most tests, as well as (Thompson, 1990: 141):

"the failure to distinguish between the different aspects of visual material in the validating tasks"

He argued that increased awareness by teachers and students alike, on the issue of visually imagery, could lead to more flexible teaching methods, which involve individual learning preferences and their interaction with the learning task at hand (Ausburn & Ausburn, 1978).

The propensity to think verbally may have deep-seated ramifications in the classroom. Thompson (1990) referred to Presmeg (1986), who suggested that Visualizers are under represented among the gifted mathematics pupils. Teachers seem to favour Verbalizers as the high achieving stars of the classroom. There were differences between visual and non-visual teachers; the result would perhaps produce an implied form of imagery instruction, according to the cognitive orientation of the instructor (Presmeg, 1986).

This was a further example of an application of the Ausburn & Ausburn (1978) notion of supplantation instructional technique research. Unfortunately, instructional designers are still left to improvise their own cueing strategies (Beck, 1991). This was due to insufficient reliable research; he described some basic cueing strategies, which have evolved, from his own research (1985; 1987; 1990).

Furthermore, measuring an individual's visualization ability, is a very difficult research area; Ausburn & Ausburn (1978); Thompson & Riding (1990); Merrill (1994), called for work to proceed in an endeavour to unlock the mysteries surrounding this cognitive processing capability.

James & Moore (1991) investigated whether the level of field dependence affects a student's ability to profit from either imposed visuals or instructions to form visual images to aid immediate recall of concrete paired-associate nouns. They believed there were possible changes in the relationship between field dependence and visual strategy as students move from elementary to high school. Their three-way analysis of variance, showed that all three main effects (grade level, cognitive style and visual strategy) were significant. There was no interaction! However, this result is not surprising, given that the purpose of their study was to investigate the relationship of cognitive style to the efficacy of imposed visuals and instructions to form visual images, as aids to immediate memory recall.
Summary

The significance of this chapter lies in the theoretical basis presented for the research programme. The selection of work was mainly taken from the paradigms of instructional science for the concept learning theories, and cognitive psychology for the information processing models. While some work has identified the need to individualise instruction (Ausburn & Ausburn, 1978), there was no evidence to suggest that we fully understand how to provide instructional strategies that are truly personalised. While the relationship between learner and task has been well researched over the years, the effects of the actual delivery methods have not. Technological solutions to courseware delivery means that decisions on instructional format are often divorced from the decisions on whether individuals are able to cope with the delivery medium selected. The next chapter deals with the computer human interaction issues related to knowledge construction.
The previous chapter identified the conceptual parameters for experimentation in this research. The selection of work was based on the link identified between cognition and instructional mechanisms. Therefore, the purpose of this chapter is to concentrate on research directed at explaining how humans learn per se, and in particular, within the context of electronic learning environments.

The overarching goal of this thesis was to test the interactive effects of instructional strategies with an individual's cognitive style, in their acquisition of computer-programming concepts. Many of the activities involved in acquisition of programming concepts, entail abstract knowledge skills.

Therefore:

*this thesis investigated the interaction of cognitive style and procedural (or abstract) knowledge acquisition.*

According to Bagley (1990), the structure of knowledge and its use in learning new concepts, is a dynamic process of transfer. Her research showed that the central components of successful knowledge transfer, are the cognitive processing of prior knowledge, and instructional format.

The axiom that enhancing instructional format with pictures or graphics is beneficial for the learning process seems to have influenced the view of how individuals learn best. For instance, the literature has categorized them as *Verbalisers* and *Imagers*. Various researchers have proposed that verbal (*text-based*) instructions suit the *Verbalisers*, and that
pictures \((\text{graphical representation})\) suit the \textit{Imagers} \cite{riding1993, ohalloran1994}.

\textbf{Testing of this theory is an important part of the dissertation.}

This chapter gives a brief review of the relevant literature starting from the early 1960's. There is a substantial amount of literature covering cognition and learning from a number of disparate research fields. An exhaustive review of literature from all these fields is prohibitive. However, a selection of key research is required to illustrate the complexities of knowledge acquisition. Although models and theories proposed in the 1960's provided a strong foundation for developing instructional design principles, it was the newer research culture of the 1970's, which shaped our current thinking. The act of human learning was analysed, setting the theoretical foundation for research into human memory and learning.

Technological advances spawned the computer-human interaction movement. During this period, instructional designers produced some classic works \cite{reigeluth1983}. Research in the 1990's paralleled the technological changes taking place in our society. As such, the literature revealed that their work was expressed in terminology resembling the linguistics of high-speed computers.

To enable a full understanding of the factors affecting knowledge acquisition, the instructional strategies devised for this research were designed using the instructional design principles of Reigeluth's \cite{reigeluth1983} Elaboration Theory, and Merrill, Tennyson & Posey's \cite{merrill1992} concept learning strategies. The programming metaphors \((\text{textual and graphical})\) were used as instructional tools.

The Cognitive Styles Analysis (CSA) devised by Riding & Cheema \cite{riding1991} was used as the screening test to divide the population into \textit{verbal} and \textit{visual} cognitive styles. For background reading, see this current chapter, sub-section \textbf{1.3 Knowledge and Cognitive Style Differences}; and Chapter Two: Conceptual Framework, topic 4.3.3 Cognitive style measurement. The data analysis incorporates Klausmeier & Sipple's \cite{klausmeier1980} Conceptual Learning Development (CLD) model. See this current chapter section 2. Instructional Format, for the CLD; and Chapter Two: Conceptual Framework, topic 4.1.2 Cognitive strategies, for Gagne's \cite{gagne1985} intellectual capabilities.
Therefore the supporting evidence forming the central theoretical tenets is divided into four sections:

- **Knowledge acquisition**: describing the characteristics of specific concept learning knowledge
- **Instructional format**: revealing empirical evidence relating to instructional strategies
- **Retention and instructional strategy**: discussing the relationship between short and long term memory research, and instructional format
- **Building electronic learning systems**: to demonstrate the current issues in applied research.

1. Knowledge and Learning

   Instructional systems rely on the analysis of learning content (*specific knowledge requirements*) within a domain of information (Tennyson & Cocchiarella, 1986). Knowledge has been identified by Gagne (1985) as concrete or declarative (*knowing the specific facts and rules*), and abstract or procedural (*knowing how to apply declarative knowledge in new situations*). Gibbs (1996) argued there was enough evidence from linguistics and psychology to conclude that people construed many concepts in terms of metaphor; and called for more research to see if, when and how, certain concepts were metaphorically represented.

   Researchers have refined their attitude towards the relationship between knowledge and learning since the 1960's. For instance, a comprehensive schema acts as a basis for classifying types of learning (Romiszowski, 1981:267):

   "**Knowledge is 'information stored' - it is something an individual possesses. Either he has it, or he has not - a go/no-go quality. Individuals differ in the quantity of knowledge that they possess""

   He argued that individuals would always differ in the quality of the results they achieve when they apply knowledge to practical tasks, because of the innate individual differences between people. Hummel & Holyoak (1997) did not report on individual's cognitive differences. Instead they argued that the cognitive architecture embodied in their computational model, called Learning and Influence with Schemas and Analogies (LISA), represented the human thought process. Consequently their approach to cognitive
individuality is generic. They postulated that LISA may help us understand why human thinking was superior to the constraints of machine generated memory capacity.

To expand on the theoretical background, the following sub-sections include:

- Knowledge acquisition
- Constructivism
- Knowledge and cognitive style differences
- Transfer of programming knowledge

1.1 Knowledge Acquisition

The inter-relationship of the human mind with the ability to learn and make decisions that bring about changes effecting both the personal learning environment and the world at large, has been a focus of educational researchers for many years. Literature on acquiring knowledge covers a broad spectrum, with each researcher concentrating on their particular paradigm.

For instance: Bruner (1960) explained that the task of teaching a task, should represent the structure of the subject-to-be-learned, in terms of the learner's way of viewing things (*a series of habits and associations*). While another view was that learners should be encouraged to play with problems (Hannafin & Land, 1997; Jonassen, 1997). They made a distinction between knowing and understanding. Understanding they said, takes time, and was achieved by allowing the novice learner to become immersed in a problem. They believed that this was the way the learner can encounter intricacies and subtleties of the concepts-to-be-learned, enabling them to explore the learning domain in rich, and meaningful ways, thereby progressing from *simply knowing* to *understanding*.

Another view was that multi-sensory instruction can improve a student's capacity to learn effectively (Diana & Webb, 1997). This instructional approach maximised the skills brought to the learning task, while minimising the experiences where their ineptitudes are emphasised.

Sternberg's (1977) approach was to concentrate on the basic information processes in analogical reasoning; while Dreyfus & Dreyfus (1986) described stages of skill acquisition as five steps from novice to an expert:

1) novice
2) advanced beginner
3) competence
4) proficiency
5) expertise
However, it was the sequencing of instruction that reflected the beneficial nature of meaningfulness to the act of learning (Mayer, 1977).

Careful consideration was given to the logical sequencing of instructional events to ensure participants were able to progress through the Dreyfus & Dreyfus skill acquisition steps (Figure:3.1).

The connection was made therefore, between an individual's prior domain knowledge and their internal representation (Sternberg, 1977). The instructional device called an advance organizer (Figure:3.1) occasionally made learning meaningful by relating new knowledge in a parallel fashion, to what is already known outside the content area (Reigeluth, 1983-a).

Another learning process often overlooked in the literature, was to make new knowledge meaningful by relating to sensory events (Rosch, 1978), or to actions already stored in a learner's experiential database (memory). Lindsay & Norman (1977) used a technological word to describe this experiential (human) database. This was a sensori-motor database, probably being the most important method we have for making new knowledge meaningful, during the early years of cognitive development (Reigeluth, 1983-a).

Figure:3.2 represents how this research utilized the power of an individual's sensori-motor database with an innovative textual metaphor for explaining conditional logic flow to a novice programmer.
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It is possible to link cognitive processes and learning objectives to specific instructional methods (Tennyson & Rasch, 1988). They proposed a model to focus on the planning of a learning environment to encourage novice learners not only to acquire knowledge, but also to improve their cognitive ability, and to extend their knowledge acquisition skills. They expanded the work of Tennyson & Cocchiarella (1986), and suggested that the learning content structuring of concept variables can be divided into two separate learning conditions, which Tennyson & Rasch (1988) described as cognitive abilities. They argued that these cognitive abilities have the potential to provide a nexus between developing integration skills from rule learning and differentiation skill development. This was the way they have been depicted in the declarative learning domain.

Royer & Cable (1975) investigated the interference of facilitory learning, whenever the materials to be learned are not easily related to something a student already knows. They argued that icon-specific facilitated learning occurs in the situation in which an initial passage read contained concrete referents, that were designed to increase the comprehension of a difficult to understand second passage. Subsequently, these findings contained implications for enhancing the learning of educational materials. Wu & Solman (1993) examined the use of extra stimulus prompts in teaching sight words. They suggested that depressed learning may be due to a blocking effect during training with compound elements, caused by the interference of pictures with written words.

To test whether this is so, this research has measured the effect of the full range of cognitive style characteristics on two types of instructional format (text and pictures).
According to Pettersson (1993-b), there was a relationship between cognitive level and mental energy consumption in different learning activities. Reading and listening are mentally and physically exhausting with dull and poorly designed material, thereby losing the reader's interest. Furthermore, he proposed there was a relationship between cognitive level and suggestive impact, for different kinds of instructional representations. Therefore, designers should be conscious of this and strive to design their learning materials (text and pictures) in the most attractive, and relevant manner possible, so that novice learners are encouraged to process the content (message) on the highest possible cognitive level.

Therefore in order to look deeper into the question of knowledge acquisition for the acquisition of abstract computer-programming concepts, it is necessary to explore the following topics:

- Accessing knowledge
- Making new knowledge meaningful
- Analogic knowledge
- Measuring categorization skills
- Using language
- Canned creativity: Script theory applied
- Schemata

1.1.1 Accessing knowledge

During the past decade, our understanding of the learning process and what were the influencing factors, has evolved steadily (Gallagher, 1994). There have been many studies conducted to investigate the changing role education now faces with an extremely diverse range of learners. Once again, the outcomes from these studies vary according to the researcher's paradigm. For instance: Brandon, Newton & Hammond (1987) in studying the interaction of children's mathematics achievement and gender, drawing on the cognitive psychology domain, took the view that social and environmental forces heavily influence how learners structure their knowledge.

There were two principal kinds of problem solving (Ausubel, 1968), trial-and-error and insightful. He described the trial-and-error approach, as a random or systematic variation, with approximation and correction of responses until a successful variant emerges. This approach implied there may be a set of activities that are oriented towards discovery of a means-end relationship that underlie the solution of a problem. He suggested on the other hand, that the most important criterion of insight, lies in the
transferability. This transferability occurs when approaches to problem solving reach an insightful solution, reflecting the transfer or application of relevant established principles, to new variants of the same problem.

There are also differing views about how we solve problems. On one hand, creativity is held by Sternberg (1988) to be a central interface between the three different intellectual functions he calls legislative, executive and judicial. He argued that legislative concerns creativity, the executive involves acting on creation, while the judicial relies on evaluating creation. On the other hand, Weisberg (1988) suggested that the relationship between creativity and problem solving relied on some kind of prior knowledge. However, there was an important connection with task-relevant prior knowledge and creativity; showing that insights are not likely to happen in the absence of a great deal of task-relevant prior knowledge. An individual's ability to suddenly produce creative ways to problem solve, does not come from anywhere (Weisberg,1988). Rather, this process involved an integrated effort, combining knowledge representation that is useable and useful for a given task.

1.1.1 (a) Frailties of prior domain knowledge

How prior domain knowledge affects knowledge acquisition is a much researched and often debated topic. Most researchers agree that it is a complex issue. Having prior knowledge is not adequate on its own (Bransford & Franks,1971); it must become activated in a semantic context. Rosch (1978) proposed that meaningful, sensori events or actions, are stored in a learner's experiential database (Lindsay & Norman, 1977). To fully evaluate post-test results, variation of knowledge attainment must be accounted for. However, the need to measure levels of prior domain knowledge is often over-looked in research. For instance, in the experiment conducted by Joseph (1987), the effectiveness of an observable imagery strategy for the encoding of verbal information was examined without concerns for the interactive effect that prior domain knowledge would have on results.

The issue of prior programming knowledge is accounted for in the experimental plan. The participants were measured for basic programming knowledge before they were given the instructional treatment, and were then measured for improvement between the pre- and post-test instructional outcomes (Griffin & Nix,1996).

A few researchers have tackled the issue of prior domain knowledge in their experiments. Several different approaches have been taken. For instance, Tennyson
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& Bagley (1991) were referring to it when they suggested that prototypes influence the ways in which we progress with the application of newly presented concepts. In Bagley's experiment, a pre-experiment screening test was used to divide the sample into Novice and Experienced sub-groups.

A further related problem, is the prior domain knowledge of the researcher. Wright & Murphy (1984) argued that people's theories often bias their evaluations of evidence, and suggested that the research conclusions might be more accurate if they were unbiased by prior beliefs.

1.1.2 Making new knowledge meaningful

The term meaningfulness can be regarded as relating new knowledge to prior superordinate knowledge (Reigeluth, 1983-a). However, there has been a misconception about the type of prior knowledge that is utilized by learners to make learning meaningful. The mistake has been identified as relating the meaningfulness of new knowledge to what a novice already knows; superordinate knowledge. This is only one of the ways learners process new knowledge. There are indeed seven kinds of prior knowledge identified by Reigeluth (1983-a):

1) arbitrarily meaningful knowledge
2) a superordinate idea
3) a coordinate idea
4) experiential knowledge
5) an analogic idea
6) a cognitive strategy (Gagne, 1985)

Therefore the instructional metaphors designed for this research, tap into this theoretical framework, to show how individuals, learning completely new concepts, draw on previous experience in an unrelated field.

A key to understanding how we learn can be found in the work of Rosch (1978). Human beings use categorization systems to access and assimilate new knowledge with their existing knowledge structures. The two general principles of categorization from her research are cognitive economy and perceived world structure. For instance: the Rosch (1978) categorization principle of cognitive economy identifies the way we conserve our cognitive resources, while gaining a great deal of information about the environment. Many researchers have acknowledged these principles.

The Component Display Theory (CDT) of Merrill (Reigeluth, 1983), has also shown how individuals categorize a general class of object (an instance), into being either a member or non-member of that specific class. Choi (1986) evaluating the contribution
of the CDT within the paradigm of instructional design; found it provides systematic operational procedures, and also offers practical procedures for analyzing and quantifying the quality of instruction, in relation to its objectives and test-items. Furthermore, it provides a checklist for the effectiveness of the instruction without any extensive formative evaluation.

1.1.3 Analogic knowledge

Nevertheless, humans have been using analogies to pass on knowledge for thousands of years.

The abstract nature of analogic reasoning is useful when explaining complex programming concepts. For instance: conditional logic flow can be translated into an everyday analogy like deciding what to wear if the weather is hot.

According to Sternberg (1977), the basic information processes in analogical reasoning are:

1) the translation of the analogy into an internal representation on which to perform other mental operations
2) indicating a response to complete an analogy solution

He proposed that inference, mapping, and application, as well as encoding and response, are all intermediate comparison operations used in an analogy solution. Furthermore, he proved mapping to be a statistically significant parameter in each of his three experiments. Hummel & Holyoak (1997) argued that they were able to simulate human analogical access and mapping.

Analogical cognitive processing occurs when the features used as a basis for association are not necessarily prominent (Winn, 1982-a). Selecting the less noticeable features between objects, requires the learner to retrieve two schemata into short-term memory, that may not have occurred together before. Hence the result may be an association that is processed as a completely new one (Winn, 1982-a). Therefore the instructional strategy of using metaphors to combine separate concepts into new ideas, promotes an individual to readjust their schemata.

Ortony (1979) identified the importance of the similarities between concepts. Since then, other work on creating analogies includes: involving realistic visuals in instructional design (Rakes, 1996); and an attempt to simulate the process of analogy generation, and to simulate the components of creative thinking (Klix & Bachmann, 1998).
Research on analogy was in an adolescent stage up to 1985; the contributions from artificial intelligence were responsible for the formation of a new research community (Hoffman, 1998). The relationship of metaphor and analogy, was not as simple as the notions depicted by the well known figure of speech, chicken and egg: analogical reasoning is a fundamental cognitive operation, allowing for metaphor (Hoffman, 1998).

However, explaining this phenomenon is complex; it is not the features or attributes (Merrill et al., 1992) that are matched, but the structure or function of the relationships (Ernest & Paivio, 1971; Rohwer, 1980) among the features expressed by the predicates of propositions (Winn, 1982-a).

Using the example that blood vessels were like aqueducts, Winn (1982-a) showed there was a new association between two objects, implying how blood vessels function. The only difference, was in the arguments of the propositions representing the information (Winn, 1982-a). That is, water for the aqueducts and blood for the blood vessels. However, he suggested the predicates describing the two propositions (blood vessels and aqueducts) are the same. It is the concepts of flow and channels to hold the flow, that are the arguments of the predicates that are different.

Ritchey (1980) carried out a series of four experiments, focussing on analogic knowledge, to investigate the role of image detail on recall. He predicted that recall of items imaged next to a simple matrix, was superior to recall of items imaged next to a complex matrix.

By measuring cognitive performance, this research will be able to identify which cognitive style is more inclined to pick out the embedded detail from which type of instructional format best.

Hosenfeld, van de Mass & van de Boom's (1997) longitudinal study revealed there was a critical slowing down in the analogical reasoning performance of young elementary school children. However, it was found that in adults, there was a difference between poor and successful analogy performers, who allocated their solution time in different ways. Successful performers spend more time encoding the attributes of an analogy, and less time processing comparisons, than the poor performers. Therefore, the strategic allocation of solution time seemed to assist with the memory load of the analogies (Hosenfeld et al., 1997).

Emphasis on presenting unrelated collections of items can also be found in the work of Merrill et al. (1992). They used the term divergent examples when presenting examples
of the concept to be learned, which were as divergent as possible to promote performance in concept classification. This means that the critical attributes of the concept to be learned depict wide differences.

The examples and non-examples presented during the instructional period for this research drew on this theoretical framework. For instance: there were four different types of example problems devised for participants to work through.

However, most computational models of analogical reasoning are domain-specific, providing a basis for both a theory of analogy, and a theory of metaphor (Dierbach & Chester, 1997). They argued that their mathematical model (abstractional concept mapping), provided a formal basis for analogical reasoning.

1.1.4 Measuring categorization skills

How individuals categorize new concepts, may affect their ability to understand and apply newly learned material, especially if the instructional strategy requires analogical reasoning.

However, can we predict how an individual will categorize new concepts?

This cognitive processing ability has been identified as the ability to determine category width (Massaro & Fergusson, 1993); this means the range of instances an individual includes in a cognitive category (Pettigrew, 1992).

Apparently, individuals vary in regard to their acceptable category widths. Some people will accept an exemplar of a category item (say a table), only if the example presented is an ideal instance with all the appropriate attributes (Merrill et al., 1992) (flat top, reasonable size, and four legs of appropriate length). While other individuals, will accept less than ideal instances (curved top and no legs) (Massaro & Fergusson, 1993).

This notion of a continuum for category width, implies a flexibility in categorization not previously acknowledged in the Rosch (1975-a) experimental literature.

Massaro & Fergusson (1993) also conducted investigations into the relationship between an hypothesized cognitive strategy of category width, and the component processes involved in speech perception. They proposed that providing a process-analysis of categorization behaviour can make insights into both category width and categorization. Directly assessing psychological processes involved in categorization, revealed that it is
possible that broad and narrow categorizers do process speech differently from one another. They report, however, that they failed to detect this difference.

Breaking the participants’ test performance data into sub-groups of cognitive style and instructional format, will provide an opportunity to analyse whether there are any significant size effects for particular combinations of cognitive style, instructional format, and programming knowledge tasks.

There were examples in the literature where researchers duplicated effort and/or have not correctly translated the original meaning (of categorization) into a new context. Firstly, there was the proposition of narrow and broad categorizers being similar to the findings from the problem solving and creativity research, when in fact, the similarities were to be found only with notions of the broad categorizers and creative processing. Furthermore, there were incorrect applications of Rosch’s prototype theory. She has reported that researchers have misused her notions of prototypical instances to restrict the categorization process, often concluding that these were misapplications of prototypical instances.

1.1.5 Using language

Although Massaro & Fergusson (1992) were unable to measure the relationship between categorization and speech processing, previous research has investigated the development of language skills as a learning tool. According to Cole (1985), Vygotsky was the first modern psychologist to show how culture becomes instrumental in shaping each person's nature. Vygotsky (1978) has argued that our ability to use language as a problem-solving tool develops during our childhood. As children, we practise using socialized speech to address an adult and turn this dialogue inward to appeal to ourselves. Language then becomes an intrapersonal function in addition to its interpersonal use (Vygotsky,1978).

It will be possible to show that adults are capable of acquiring new concepts, when given appropriate instructional mechanisms that tap into their previous worldly experiences.

Piaget (1926) referred to an inner dialogue, as being the mental pictures of social interaction in an adult's mind's eye; of collaborations or opponents with whom eventual disclosure will take place. This is the way our minds anticipate a social interaction through a rehearsal process (Piaget,1926).
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Important distinctions and relationships between the use of processing behaviours (tools), and the development of speech (signs), were initially made by Vygotsky, during the early 1920's. Tools were described, as being the processing behaviour humans instigate when accomplishing tasks. Tools are externally oriented and serve as conductors of human influence on the object of the task. Sign use is an internal activity, which changes nothing in the object of the task. This internalization is an individual act aimed at mastering oneself (Vygotsky, 1978).

It will be possible to show which individuals possess the ability to make this transfer, from the external representation of a new programming concept (the tools from an instructional format), to the inner activity (the sign use), required for understanding how to implement newly learned concepts, in a different context.

Speech possesses a synthesizing function, which in turn gives rise to the more complex forms of cognitive perception (Vygotsky, 1978). Speech requires sequential processing. Each attribute of speech is separately processed, then connected to a sentence structure. This identifies speech as an analytical act. Written language (text), becomes direct symbolism that is perceived in the same way as speech. Speech also helps to create a perception of time.

Our memory serves to combine attributes of the past and present visual input (tool and goal), into one field of attention (Vygotsky, 1978). Attention includes a whole series of potential perceptual fields that accumulate over time. Adults internalize external signs as a means of remembering. To convert remembering to a mediated activity, visual cues must represent the object. Mediated memorizing occurs in adults, even in the absence of special external aids (Vygotsky, 1978). However, there is still little understanding of how internalization acts as a prime mechanism of conceptual change (Brown & Palincsar, 1989).

1.1.6 Canned creativity: Script theory applied

Research has shown that the functioning of the human mind holds many secrets, not the least of which is the explanation of the creativity process. Some researchers believed that creativity can be produced artificially, by using machines to replicate the human creative processing ability. For instance: Ausubel (1968-c) believed that removing the human being from the creative process was to change the basic conception of creativity. He argued that humans must figure in this scenario if only in the outcome, to reject or accept. However, Sternberg & Lubart (1996) argued that because confluence theories
are based in psychological theory and are therefore susceptible to experimental test, they offer a relatively new and more promising approach to the study of creativity. While much of the research effort has been tinged with associations to mystical beliefs, they suggested that it is possible to model cognitive-processing.

Moreover, according to Schank (1988:237):

"creativity is not such a mysterious process... it.... depends on having a stock set of explanations and some heuristics for finding them at the right time and for tweaking them after they have been found"

Furthermore, creative solutions and creative explanations can be found mechanically, and it should be possible to design mechanisms whose output is creative. Explanation patterns function in much the same way as a script.

Bower, Black & Turner (1980) described a script as being a generic memory structure in a person's head. They provided evidence to support the argument that many of our interactions in life seem to follow set patterns; we devise scripts to conceptually guide our behaviour. Jenkins (1980) argued that the field of memory research is moving toward contextualism. However, this paradigm involved a top down, event driven approach to define memory functioning.

*It may be possible to test out this theory using the programming metaphors as innovative instructional tools.*

1.1.7 Schemata

One explanation of how the human mind operates, was to propose that memory structures are comprised of a set of active schemata (Bobrow & Norman,1975). They argued that each set was capable of passing information and requests to other schemata. They postulated that a context-dependent description was only precise enough to disambiguate the reference within the context in which the original situation is passed. Furthermore, they specified that one-schema can only refer to another, using a description, which is dependent on the context of the original reference (the input). These schemata are active processing elements, which they suggested are activated from input data, and triggered by higher level purposes and expectations.

Wittgenstein (1963) explained that natural categories and concepts are commonly characterised and understood in terms of family resemblance. In other words, a network of similarity relations that link the various members of the class. Tversky (1977) reformulated the work on concepts of similarity, prototypicality, and family
resemblance. Although they were connected, they have not been previously related in a formal explicit manner. His research presented these concepts in a unified framework, where they could be viewed as contrasts, or linear combinations, of the measures of the appropriate sets of common and distinctive features.

The work of Rosch and her associates was therefore confirmed by Tversky (1977) in his research (Tversky, 1977:348), which:

"demonstrated that both natural and artificial categories are commonly perceived and organized in terms of prototypes, or focal elements, and some measure of proximity from the prototype"

Practice has consistently been shown to improve concept learning (Tennyson, Chao & Youngers, 1981). Most of the mathmagenic literature supports that conclusion as well (Jonassen, 1988). However, research by Jonassen (1988) also demonstrated that prototype treatments obviously produced learning during a lesson.

Reigeluth & Stein (1983) have explained this as a zooming-in process, involving steps or levels of elaboration, with each step providing more detail or complexity. This type of strategy forces learners into deeper processing (Jonassen, 1988). Previous research (Jonassen, 1986; Park, 1984) showed that the prototype concept acquisition strategy is less susceptible to decay on retention tests.

The self-paced instructional booklets prepared for this research model the Elaboration Strategy. It should therefore stimulate deeper processing, and should produce performance that is even more resistant to forgetting.

1.1.7 (a) Elasticity

Therefore, the zooming effect of concept elaboration involves the human mind in a series of context-dependent shifts. According to Wittgenstein (1963), there was something very elastic about the concept of a representation of what is seen (an internal copy) and an original item. The concept of what is originally seen and the representation of what is seen (the copy) are intimately connected. However, this was not to mean that the two phenomena are alike (Wittgenstein, 1963). He suggested that when individuals see a physical representation, they do not need to (directly) think about it. Moreover, when individuals think of what they see (a visual experience) without the physical representation, they do not need to think about it.
This confirms the orthogonal nature of Riding & Cheema's (1991) cognitive style construct by implying that the act of thinking and the subsequent internal processing of information are independent.

Ausubel (1968-c) described a similar tension between reality and prior experiences, when he suggested that the cognitive content an individual derives from written or spoken words is a highly simplified, abstract and generalized version of actual real world realities, combined with the actual conscious experiences the individual has acquired.

Novice programmers become more elastic in their approach to problem solving once they have gained the skill (or cognitive strategy) to write an algorithm (procedural knowledge).

Therefore expert programmers have abstract, conceptually based representations of programs. Conversely, novice representations were based on common control words (Gick,1986).

There are differences in the problem solving strategies used by experts and novices. Experts use a strategy described as working forward, and novices employ a working backward strategy, according to Simon (1978). In the working forward approach, experts work from the given information to the problem goal using the given equations and calculating the unknowns, until the solution to the goal of the problem is found. Furthermore, they will bypass reporting on the equation being used, reporting instead on the result of the equation. Experts are able to verbalize the actual physical situation, because they have worked through the five stages of skill acquisition (Dreyfus & Dreyfus,1986) (see sub-section 1.1 above), whereas novices verbalize only the equations, because they have not yet worked through these skill acquisition stages.

1.2 Constructivism

Most of the literature reviewed above has focussed on instructional frameworks and cognitive processes. However, during the 1980's an alternative voice emerged from the research, which placed an emphasis on the importance of the individual in the learning and memory domain. Although there is still much debate amongst instructional theorists and instructional designers (Dinter,1998), the constructivist approach has continued to gain support through to the present day.
Learners do not learn in a passive manner (Perkins, 1991). They must actively engage in their learning (Jonassen, 1997). This means they will proceed through three learning stages:

1) interpret the topics to be learned
2) elaborate these interpretations
3) test these interpretations

Bruner (1966) described how human cognition reached beyond an automatic response as a reaction to input. This was known as the BIG (beyond-the-information-given) instructional strategy. The contrasting WIG (within-the-information-given) strategy holds back on direct instruction. Perkins (1991) explained the issues that surround the notions of technology meeting constructivism. He argued that on the one hand, BIG constructivism allows students to be fully engaged in a number of thought-oriented activities, that directly challenge them to apply and generalize their initial understandings, and refine their learning strategies along the way. Furthermore, he believed that BIG instructional strategies are able to produce contrasting concepts (like showing the distinction between heat and temperature) through implementing computer based imagistic mental models. While on the other hand, WIG produces learning by concepts rediscovered (like not offering the official characterization of heat versus temperature); the student would be encouraged to provide an intuitive explanation, with the instructor only stepping in at the last moment. Technology can provide simulations to utilize both instructional strategies.

Another approach to instructional design is known as anchored instruction. This is the term the Cognition & Technology Group at Vanderbilt (1992) applied to instruction. It means the instructional strategy engages the learner in problem-rich learning environments. Anchors create a macro-context (CTGV, 1992), in which all the stakeholders are involved in the learning programme. For instance: the subject matter experts, teachers and students from diverse backgrounds combine to communicate in a collective learning experience. They have also proposed that the macro-contexts provide the potential to facilitate experimental studies for research.

1.3 Knowledge and Cognitive Style Differences

Understanding the literature relating to individual learning attributes is challenging. Terms describing how individuals process information change according to the researcher's paradigm. Early attempts during the 1950's and 1960's by psychologists researching cognitive abilities and processes produced a fragmented list of models and labels, derived mainly from single experiments (Riding & Rayner, 1998). They argued that cognitive style, is understood to be an individual's preferred and habitual approach to organizing and representing information. Pask (1976) proposed that the holist/serialist distinction, was an example of different learning strategies, rather than learning style.
Earlier research described cognitive processing ability in a number of ways. Field dependent/independence was one of these. According to Witkin & Goodenough (1981), field independent individuals relied on an internal frame of reference (they can isolate their thinking processes well), while field dependent individuals rely on an external frame of reference (they require additional stimulation to pick out or disembed detail). The field dependence/field independence continuum, as it applied to learners, identified the degree to which they will interact with the instruction as presented, or will analyze, reorganize and synthesize the instructional material to make the content more meaningful and memorable to them (Ausburn & Ausburn, 1978). The studies conducted by Dwyer & Moore (1991), and Moore (1985), provided evidence to support the argument that field dependence and field independence have become important variables to instructional designers. Dwyer & Moore (1991) examined the effect that differentially coded (black and white and colour) illustrations had on students who were classified as field dependent, field neutral, or field independent. They argued, that the process of colour coding instructional materials, for some types of learning objectives, may reduce achievement differences attributed to differences in cognitive style.

There was evidence of conflicting views relating to this field of research. For instance: Howell (1972) supported the Lowenfeld's (1945) visual/haptic type dimension. However, in Moore & Bedient's (1986) description of Lowenfeld (1954) and Howell's (1972) work, they mix the presentation of visual stimulus in a sequential manner, with the cognitive characteristics of visual material. There seems to be a problem with their description of haptic types that appeared to say that field dependent individuals and visual types tend to be similar to field independent individuals. For instance, they claimed that visual types, can mentally retain visual imagery, while haptic persons cannot. They claimed that field dependent individuals, may have difficulty in retaining a visual stimulus, when the materials are presented in a sequence. Furthermore, that it would be reasonable using multiple (or simultaneous) imagery, to reduce the visual task for field dependent participants, as well as the field independents.

Riding & Cheema (1991) were able to condense the earlier style constructs, into two families of cognitive style. Their Wholist-Analytic and Verbal-Imager continua reflect an integrative model of cognitive style (Figure:3.3). Riding (1991) developed a computer-based test, known as Cognitive Styles Analysis (CSA), to measure an individual's position along these two cognitive dimensions. (See Chapter Two : Conceptual Framework, topic 4.3.3 Cognitive style measurement.)

The CSA was used as a screening test for this research, to sub-group the participants based on their cognitive style.
Rayner & Riding (1997) were able to identify a third group of models which lay outside of the earlier research on cognitive processes, which also became known as cognitive or learning styles; these models more correctly, should be called learning strategies. King (1997) concurred, by describing learning style as a student's consistent preference in learning strategies. He posed the question: why do brain-antagonistic practices pervade so much of educational practice? King (1997) advocated for less stress inducing methods preferring instructional methods that work with, instead of against, the human brain's natural processes for accessing, storing, and retrieving information.

However, there was a credibility gap associated with the measurement for cognitive style, by the earlier researchers (Riding & Rayner, 1998). They argued, it is an individual's ability (Griffin & Franklin, 1995-6) rather than style, that is measured by the famous Witkin (1950) Embedded Figures Test (EFT). This revelation now throws into question, a whole series of earlier experiments.

Therefore, this dissertation has taken a controversial stance by adopting the Riding (1997) cognitive style construct to develop a fresh approach to instructional science.
1.4 Transfer of Programming Knowledge

The teaching of computer-programming skills, can be valuable to some students, in the development of meta cognitive abilities (Brown, 1996). However, in the highly analytical learning domain of computer programming, the novice is frequently left to develop *procedural* (or abstract) *knowledge* on their own. As such, they never have the opportunity to experiment with generalized *procedural* (or conceptual) *knowledge processes*, while learning initial concepts (Bagley,1990). Moreover, they are often exposed to worked examples that are generated by expert programmers. She argued that in this circumstance, the novice may not be able to retrieve the appropriate schemata without being taught the rules (*declarative knowledge*), the processes (*abstract or procedural knowledge*), and the *conceptual knowledge* associated with the programming language. Novices were therefore left to rely on common sense, to extract the necessary procedural processes (*conceptual knowledge*) necessary to build relevant schemata (Bagley,1990). When this happened, they may regress, due to their failure to draw any benefit from the learning experience (King,1997).

However, there are now a small number of effective interactive programming learning tools; known as programming by demonstration (PBD). For instance: Neufield, Kusalik & Dobrohoczki (1997) developed a colour coding process (tagging), which a programming student can use to *trace logic flow*. This was a new visualization system that traced unification through a *Prolog proof tree*, to help novice learners follow the programming steps. This system placed the novice directly inside the logic flow process. Consequently, the designers of these systems were still expecting the novice to posses *procedural knowledge*.

Modugno, Corbett & Meyers (1997), and Smith & Webb (1998), devised *visual instructional strategies* as programming learning shells. In each case, they have proposed that their graphical language improves comprehension. Modugno et al. (1997) rely on the *visual language paradigm*. Their comic strip metaphor has proven to be more successful than traditional *text-based* programming languages, for increasing the power of PBD systems, for a *visual shell environment*. Smith & Webb (1998) used a type of *visual interpreter*, which promoted participants to follow the *procedural logic flow*, while learning to program in the C language.
2. Instructional Format

Now that we have reviewed some of the factors, which affect knowledge acquisition, this section will review the literature covering ways in which instructional material can be enhanced to facilitate learning. Sternberg (1998) argued that instruction was not helpful, when students' preferred mental representations (verbal, spatial) were not taken into account. Therefore, learners instructed in a way that does not match their preferred mental representation will use the strategy that is easiest. As described in Chapter Two: Conceptual Framework, Ausburn & Ausburn (1978) were amongst the earlier researchers linking instructional format with individual differences in learning mode. Many subsequent researchers appeared to lose sight of these individual differences, and the common belief that pictures will enhance learning performance for all, was promoted.

However, there was evidence of agreement in the instructional science research community two decades ago. Merrill & Tennyson (1977) concentrated on four primary instructional design variables, for organizing content into a single presentation strategy:

1) definition
2) expository instances
3) interrogatory instances
4) attribute elaboration

They demonstrated that the structural form of the information, has an effect on the form of knowledge an individual codes into their memory. Tennyson & Cocchiarella (1986) cited Klausmeier's CLD model, as another fine example of an empirically based instructional design. This model represents four levels of conceptual development:

1) *concrete* recall of the critical attributes
2) *identity* recall of learned examples
3) *classificatory* generalize to newly encountered example
4) *formal* discriminate between newly encountered instances

Furthermore, they acknowledged the learning and teaching concept strategies of Klausmeier & Sipple (1980) in taking the cognitive view on conceptual learning (Klausmeier, Ghatala & Frayer, 1974).

The Klausmeier & Sipple (1980) views of *concept attainment* were similar to Gagne's definition of *concrete concepts*, which were analogous to attaining the *identity* and *classificatory levels* in the CLD.
The higher levels of concept attainment in this model apply to:

5) concepts that have more than one example
6) observable three-dimensional examples
7) examples that are defined in terms of intrinsic attributes, functional attributes or both

In the first of Klausmeier's levels, the concrete level, individuals have attained the concept as an object only. People can discriminate the concept from other objects and represent it internally as an image, and remember the representation. For instance: someone possessing an image of a clock. The identity level was inferred by the individual's recognition of an object in another situational context, or sensed in a different modality such as hearing or seeing.

In the second level of concept attainment, people not only discriminate, but they also need to generalize the forms of the particular object as equivalent across the different contexts in which the same object is experienced. For instance: a person recognizing the clock in a different setting.

The third level of concept attainment, the classificatory level, occurs when an individual responds to two or more different examples of the same class of objects, events, or processes. For instance: when the clock on the wall and the one on the desk are recognized as being different visually but have the same functionality. At this level, the attributes cannot be clearly distinguished. An individual may not be able to express the differences between the objects verbally at the classificatory level.

The fourth level of concept attainment is called the formal level. It is at this level, that an individual can discriminate the attributes of the concept, and name the defining attributes giving an acceptable definition of the concept. It is only when people can accomplish all four levels of concept attainment that it is inferred that they have learned the concept.

While researching autonomous instructional strategies, Royer & Cable (1975) suggested, that we should not be able to show an effect, when the materials are readily understandable in- and of- themselves. Furthermore, Bagley's (1990) work with novice and experienced programmers, on the interaction of structured vs unstructured instructional format, supported this point. She found that when learning a new programming language, the novice performs best with structured learning materials, while the expert (or experienced programmer) performed best with unstructured learning materials.

Taking this notion of autonomy in learning materials one step further, Laurillard (1993) concurred with the notion that within reasonable limits, we should be able to design
curriculum materials, such that a student never encounters materials that they are cognitively ill-prepared to learn.

Therefore, to respond to the computer/human instructional environment issues relating to instructional format, the discussion is divided into sub-sections that involve:

- Mnemonics
- Information processing
- Instructional strategies
- Learning content structure: Automated concept formation

2.1 Mnemonics

Humans have been using drawings to convey meaning, since the beginning of time. The concept of notationality (Goodman, 1968), provided a continuum for classifying symbol systems (Salomon, 1979). On one end of his dimension, there were symbol systems that were described by Goodman (1968) as notational, while at the other the non-notational. The characteristics of a notational system are a one-to-one matching of the element, and its referent. Similarly the characteristics of a non-notational system, are revealed as not having a one-to-one relationship between the element, and its referent.

However, non-notational systems, can lead to multiple meanings due to ambiguous mapping with the field of reference. The kinds of information an individual extracts from a non-notational symbol system varies, according to the way the individual reads them (Salomon, 1979).

This research will show how it is possible to provide a notational transfer agent, to assist with this process when a learner with a particular cognitive style cannot cope (Figure:3. 4).

Kulhavy, Stock, Peterson, Pridemore & Klein (1992) provided an example of a notational knowledge transfer, when they suggested that feature information that is successfully located within a map image can be used to retrieve associated information within a human's verbal store.

However, this has not been possible in the past, and Levin (1981-b) questioned the reliability of various mnemonic systems. They may only work for the original author. He emphasised the importance of using explicit and implicit keywords (adding textual captions) to pictures.

The design of the text-plus-graphical metaphors for this research draws on this theoretical view.
The Atkinson (1975) mnemonic keyword, was an instructional strategy that detailed *acoustic* and *imagery links*, from the Aptitude by Treatment (ATI) model (Levin, 1972). Paivio (1971), Rohwer (1973) and Bower (1994) were three other researchers who have made significant contributions to this area. Although it may only prove to be sound in certain circumstances, Rohwer (1980) believed that mnemonics are adaptable to learner differences, and may help to foster certain valued skills like creativity and in the promotion of logical thinking strategies (he called this *systematicity*). The consensus of researchers was that mnemonics were useful tools to aid human's information processing.

2.2 Information Processing

Defining how individuals process information is a complex issue that has been the focus of much research. Significant work began in the early 1970's and many of the current theories have expanded on models developed during this period. The race is on for providing Web based courseware! This is a dramatic shift in instructional delivery media. It has given rise to a proliferation of investigations into how we construct mental images (Kosslyn, Cave, Provost & von Gierke, 1988).
Therefore, in relation to explaining human ability to process information, the discussion deals with the following topics:

- Conceptual learning techniques
- Cognitive processing
- Prototype theory
- Prompting strategies
- Visual/verbal processing

2.2.1 Conceptual learning techniques

Kosslyn (1988) led the way, with his notions that objects in images are constructed a piece at a time. Roth & Kosslyn (1988) argued that mental images of 3-dimensional objects were generated in a near-to-far sequence. Kosslyn (1995) believed there were two ways to form images: by retaining perceptual input (on-line), and activating information stored in long-term memory. Bruyer & Scailquin (1998) supported the notion, that the architecture of visual working memory consists of a slave system devoted to (nonverbal) visual information, and another slave system, devoted to spatial information (Logie, 1995).

Crosby & Iding (1997) recommended for future research on exploration of the development of mental models of scientific phenomena, via instructional strategies appealing to visual or verbal cognitive processing. Their work involved a multimedia physics tutor. They were able to show learners experienced most trouble in dealing with abstract material, when presented in the initial stages of each learning segment.

The preoccupation to unlock the mysteries of the visualization process, eventually leads to a discussion of the cerebral hemisphere research. Riding, Glass, Butler & Pleydell-Pearce (1997), measured individual cognitive style differences in EEG output. However, some researchers are now revising their previously held opinion, on how we process text (left-hemisphere) and images (right-hemisphere). Kosslyn (1987) claimed, that the standard view that imagery is a right hemisphere phenomenon, is incorrect.

The investigations into this issue are intricate. Apparently, mental images can be generated in different ways, when cued by either left or right cerebral hemispheres (Kosslyn, Maljkovic, Hamilton, Horwitx & Thompson, 1995; Laeng, Peters & McCabe, 1998). Interest from this research paradigm is also developing relating to the effects of aging (Kosslyn, Margolis, Barrett, Goldknopf & Daly, 1990; Brown, Kosslyn & Dror, 1998). The spread of technology means that more people have access to machines which process information. Therefore, research which is relevant to this issue of
expanding technology, is shaping opinion that (an active cerebral) lifestyle, can have an effect on preserving cognitive ability, at an advanced age.

Simon (1972) postulated, that it was the noticing process, in which individuals extracted information stimulus, recognized particular components of the stimulus, and the relations among them, thereby storing as a result, particular relational structures, or sets of relational structures, in short term memory. He argued, that when two objects are noticed in relation to one another, it was the relation that was noticed, and became the basis for anchoring the association between the two objects. Hence, there was a close interdependence, that appeared to exist between the noticing processes, used in extracting information from external stimuli, and the fixation (or anchoring) processes, used to store information in memories.

2.2.2 Cognitive processing

Meanwhile, from literature more directly aligned with instructional science, Klausmeier (1992) described mental constructs, as the fundamental agents of all thinking processes. His CLD model was devised from formal concept-learning experiments, behavioural analyses of the concept-learning tasks used in experiments, and theoretical perspectives on concept learning from leading researchers. At the time, his model provided a new approach for not only thinking about concept learning per se, but also for conducting related research. (See this chapter, section 2. Instructional Format, for a description of the CLD.)

2.2.3 Prototype theory

The Prototype Theory (Rosch & Mervis,1975; Rosch,1977) is now well established. Hampton (1995) proposed a Prototype Theory Concepts (PTC) model, to assist instructional science. He identified that the element of abstraction was the essential element required for a successful model of prototype. The four types of prototype models are:

1) attribute free (Posner & Keele,1968)
2) spatial or dimensional (Rosch, 1978)
3) featural (Rosch&Mervis,1975; Tversky,1977)
4) attribute-value based (Merrill et al.,1992)

Hampton (1995) maintained, that the latter model remains true to the original notions of PTC, because it introduced the notion of a contrastive set (this means size or different shades). However, he also acknowledged that the listing of features in the featural models, capture the spirit of the original Rosch & Mervis family resemblance.
According to Hampton (1995), the critical change introduced in the *featural model*, is the notion of abstraction; it has fewer features for superordinates. This means that some information is left unspecified. Researchers argue that this is very important.

The metaphors designed for this research draw on the featural model to generate the choice of graphics used. Figure 3.5 shows one such *graphical metaphor*, which depicts a family waiting to go into a room. It conveniently lacks fine detail. However, the message of people about to enter a room is conveyed instantly.

However, it was not only the common concrete objects of the real world that Rosch's (1975a) work reported on. The question of the structure of the representations, which were generated by the mind, when hearing a category term, and understanding its meaning, were also investigated. Artificial categories were under investigation by Rosch & Mervis (1975), because they believed it was possible to introduce attribute structures as independent variables in a controlled environment, with the development of prototypes studied as the dependent variable.

She supported the notion, that there were different levels of cognitive (*or information processing*) in perception. For instance, her results showed that colour was coded quite concretely. She identified two research areas; the *structure of categories and concepts*, and the *nature of mental (internal) representations*. She inferred that information which facilitated a response in learners, was located in the *external* representation of the instructional event, generated by a Rosch *prime (or instructional cueing mechanism)*, in a proactive manner; that is, in advance of the learner receiving the stimulus. (See Chapter One: Introduction, sub-section 3.2 Visual, for the description of the Rosch *priming technique*.)
2.2.4 Prompting strategies

More recently, simultaneous prompting was found to be effective in teaching a chained task to elementary-aged students with moderate intellectual disabilities (Muraida & Spector, 1992-93). They suggested that since chained tasks involved large curriculum segments for students with moderate and severe disabilities, replicating these results across students of diverse educational characteristics and ages, and in a variety of instructional formats, was needed to build the external validity of simultaneous prompting.

Although this research related to prompts for producing an action (equivalent to stimulus response research) they have not included the necessity to involve problem solving and conceptualization skills.

This research will show the interactive effects of cognitive style and instructional format in problem solving tasks for programming. It will be possible to predict the probability of achieving each task for each cognitive style.

2.2.5 Visual / verbal processing

The link between visual and verbal cognitive processing was difficult to quantify. Research towards a theory of visual learning, however, represented an exciting direction for education psychology (Mayer, 1993). He advocated a dual coding approach to knowledge construction (Paivio, Yuille & Smythe, 1966; Preim, Raab & Strothotte, 1977; Worthen, 1997; and Diana & Webb, 1997), when describing the cognitive processes that are used in comprehending graphics, as well as the mental representations that are constructed and used to answer questions.

However, visualization investigations using self-report data collection methodologies, may be somewhat flawed (Thompson, 1990). He argued that when researchers suggest their participants to visualize, this is just what occurs.

Participants for this dissertation were unaware of the visual nature of the data collection. Instead they were fully aware that the purpose of the research was to investigate instructional format for the acquisition of programming concepts.

The reliability of the relative effectiveness of a mediator production method, and mediation instructions, that did not require the research participants to draw or write the mediators, was investigated by Paivio et al. (1966). According to Paivio & Forth (1970), the results from these studies have not been obtained in any previous study.
They explained, that the finding that paired-associate recall was better for concrete nouns (like salad-elephant) than abstract pairs (like comedy-infection) was not new, but the magnitude of the difference is worth noting. Furthermore, this striking finding dramatised the conclusion that imagery-concreteness was the most effective semantic attribute yet identified among familiar words (Paivio, 1969).

The magnitude of effect (Cohen, 1977) will be measured to compare cognitive performance (on programming tasks) within cognitive style and between cognitive style and instructional format.

However, Denberg (1976-77) described a facilitating effect using unusual pictures that were depicting only part of the sentences they accompanied. The scope of potential interactions among print, pictures, and learner processes is broad (Levie & Lentz, 1982). A distinctive picture used to provide extra linguistic information, when overlapping text content may act as a mnemonic aid. Textual prompts may be needed if learners are to notice and process this information. Therefore, the effects of text illustrations depend on how they are used, both by learners and by those who design instructional text (Levie & Lentz, 1982). They suggested that enumeration, and description of these uses, will require careful analysis and detailed experimental study.

Both isolated graphics (or pictures), and textual illustrations, were used as learning tools in this research.

A connection was made between mental images and numeracy skills (Ernest, 1983:30):

"Recently I have become fully conscious of the fact that I have, and for many years have been using, a mental image of a number line. The image is a curving line, which recedes from me in three-dimensional space. The shape of the line is always the same, as are the locations of the labelling numerals along it. When I use or think of a natural number, the position of the number of the line and the numeral are automatic connotations. Unlabelled parts of the line represent the order relation rather than the real continuum, although non-integral numbers appear in close up. My number line, ...... ...... ......, resembles a telegraph wire following a meandering road up a steep hill. The scale increase is logarithmic rather than linear. The image has a fixed location in my mental space and to look more closely at the numbers, around 100,000 say, I zoom in on the line. I cannot bring the line toward me".
Mental images of a number line are well known to psychologists (Ernest, 1983). He tested the connection between mental images of a number line and numeracy, by circulating a questionnaire among the staff of a distinguished teacher training college. Given that the survey was rather limited, the results suggested the following tentative conclusions. Overall, it seemed that having an internalised number line was a correlate, and possibly an attribute, of numeracy. The ability to redirect attention on a single number line image was frequent among the numerate and infrequent among others, while linear images of time were frequent irrespective of numeracy. When considering his conclusions, it must be borne in mind, that his five numeracy groupings were those of a sample and not of the population as a whole. The results were put forward as plausible conjectures, which stand in need of wider testing and more critical evaluation. Furthermore, the sample tested was atypical (they were academics in the age range 30 to 60, who are extremely literate and numerate relative to the general populace). The hypothesis that mental number lines were largely learnt, rather than self created, was considered worthy of the attention of mathematics teachers (Ernest, 1983).

Cross-cultural research by Rolandelli, Sugihara & Wright (1992), indicated that different television processing strategies were employed by Japanese and American children. Japanese children's enhanced iconic processing skills, may lead them to employ the visual component of television for processing information more prodigiously than American children. More information is conveyed in English by the spoken rather than written form, whereas in Japanese, more information was conveyed in the written form (Suzuki, 1977). There was a heavy reliance on graphical representation for the Japanese written form, due to the simplicity of their phonetic system which has 102 syllables, compared with 3,500 in the English language. As a result, the nature of the Japanese language can lead to greater development of iconic or visual-spatial processing skill, among Japanese (Suzuki, 1977). This was evidenced by Stevenson, Stigler, Lee & Lucker (1985), and suggested by Rolandelli et al. (1992). Results showed that Japanese children performed better on spatial relation tasks and scored significantly lower than their American counterparts, on tasks of verbal memory.
2.3 Instructional Strategies

Research has shown there are important relationships between learning and instruction. Instruction involves the control of learning processes (Shuell, 1980; Winn, 1982-a; Reigeluth, 1983-b). It induces learners to use learning strategies for particular tasks (Winn, 1982-b). Instruction therefore operates externally to the learner (Figure: 3.6), while learning involves the internal processing by the learner (Winn, 1982-a). Mental skills are those processes that learners use productively in learning. He proposed that most people use imagery as a cognitive process. However, only some learners are mentally skilled in its use. When learners apply particular mental skills to a learning task, these skills are said to be functioning as learning strategies (Winn, 1982-a).

The next chapter deals with the internal/external nature of instructional strategies as event conditions, within a framework, named the conditions-of-the-learner by Reigeluth (1983-b).

Instructional strategies have two components (Rigney, 1978; Winn, 1982-a). The operating task was the first component, providing the way for inducing novice learners to adopt particular cognitive processes. For instance: when instructional materials explicitly require learners to form images. The second instructional component (Rigney, 1978), was the learner capabilities component.
Learning strategies have two origins (Rigney (1978). In the first instance, when learners are told what strategies to use, and secondly, when learners are capable of deciding what learning strategy to adopt for a particular task.

Instructional strategies have been distinguished between detached and embedded (Rigney,1978; Winn,1982-a; Reigeluth, 1983-a; and Meyer,1985). Detached strategies (Rigney,1978) and detached activators (Meyer,1985), are independent of the subject matter. Embedded activators can include pictures, diagrams, mnemonics, and analogies (Reigeluth,1983-a). These two instructional strategies occur when novice learners are told to use a particular cognitive process. For instance: when instructional material required a learner to recall information previously presented. A characteristic of this type of instruction is to ensure that the learner must follow a particular strategy to complete a certain task.

Examples of detached and embedded instructional strategies used for this research are given in Figure:3.7 and Figure:3.8.
Visualization in learning involves representations and processes that are picture like, contain form, size, pattern, and even colour (Kosslyn, 1980). While visualization in instruction, on the other hand, comprises embedded and detached instructional strategies that promote internal visual processing of information.

Furthermore, these visualization strategies can include highly visual components such as pictures and diagrams as well as non-visual components, such as verbal instructions given to learners to form images (Winn, 1982-a).

The differences between the verbal and visual approaches to instructional strategies, are defined below as:

- **Verbal exposition**
- **Visual representation**

### 2.3.1 Verbal exposition

We are more comfortable using verbal rather than visual communication (Wileman, 1993). He argued this may be due to our early school days, where the instructional emphasis was on reading and the use of the spoken word for learning subject matter. Merrill, Li & Jones (1990) describe this instructional strategy as verbal exposition. They proposed it can be the mere telling, an illustration, or the demonstration of an instructional event. Verbal exposition can also take the form of diagrams and charts (Winn & Holliday, 1982). This form presents logical relationships among concepts-to-be-learned in a spatial layout.

The power of verbal exposition was also recognized in the literature by a number of well-known researchers. For instance:

1) **keyword method** Atkinson (1975)
2) **verbal associations** Merrill & Tennyson (1977)
3) **computer-based text** Jonassen (1985)
4) **text sentence structure** Gibbons & Fairweather (1988)
5) **inadequacy of verbal cueing** Romiszowski (1983)

However, words are only the primary vehicle in instruction (Gropper, 1991). Learners need to transfer from the verbalised skill, received during the instructional event, to an appropriate skill in some other mode.

This research will show that in the learning domain of programming, this internal/external transfer process is more difficult for particular cognitive style combinations than others.
There are other forms of instructional exposition, besides verbal, pictorial, and graphical in representing single words, whole sentences or labels. They are used to define objects, and actions (Wileman, 1993). These verbal symbols are usually specific to a particular language, and as such, may be highly abstract in nature, whereas pictorial symbols are highly realistic and very concrete (Wileman, 1993). However, some graphical symbols may be very difficult to read.

Therefore to tease out the issues relating to verbal instruction (text-based) the following points are raised next:

- Structure of text
- Structural relationships

2.3.1 (a) Structure of text

Research shows that a written communication is more efficient and effective, if it follows a writing plan.

Therefore:

- the instructional strategies used for this dissertation drew on the instructional science tenets as described by Reigeluth's (1983-b) Elaboration Theory (this means that the instruction begins with epitome statements, highlighting an overview; followed by expanded instructional sequences), and Merrill et al.'s, (1990) verbal exposition and inquisitory strategies.

The verbal exposition strategies (Figure:3.9) present the facts, and knowledge declarations early in the instructional sequence, while the inquisitory strategies (Figure:3.10) expect a response from the learner.

The term writing plan, was used by Meyer (1985), to describe text structure. He presented a scheme for examining the conversation between writers and readers. This model identified three variables that influence comprehension of text:

1) writing
2) text
3) reader

Writers must evolve some general plan of what to communicate, and the reader must be able to follow that plan (Meyer, 1985).
Text evolves, therefore, through an editing process where the written passages were compared with the writer's mental representation of the topic, audience and writing plan to identify and correct errors (Meyer, 1985). Readers were only able to view the final edited form of the text, without the benefit of knowledge of the writer's original intentions. Therefore, readers may develop ambiguous relationships among ideas presented in sections of text, where writers have not clearly specified their writing plans. The ways suggested by Meyer (1985), for writers to signal their plans to their
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readers to reduce the possibility of misunderstanding, resembles the Rosch (1978) *principles of categorization*. Evidence of this similarity can be found in Meyer's (1985) notion of presenting a topic as a network of related ideas. Meyer (1985) presented these ideas in an hierarchical structure.

This hierarchical structure, can also be found in the instructional design paradigm for teaching concepts by Reigeluth (1983-b), and by Merrill et al. (1992), as well as in Reigeluth's *Elaboration Theory*. Writing plans cue readers to the writer's perspective, by demonstrating how the reader should view the topic content. In addition, they are similar to the Rosch (1975b) notion, of a priming mechanism; and as such cue readers, highlight and superordinate the main ideas or message of the writer (Meyer, 1985). She suggested, that effective written cues can also subordinate major details that support the main ideas, and thereby, further subordinate, interrelate, and sequence the very specific topic detail.

Research has shown that readers are more effective, when the information has been logically organized, with a visible writing plan, than when the information has been presented in a disorganized, random fashion (Meyer, 1985). *Embedded activators* (Reigeluth, 1983-a) force the learner to use a given cognitive strategy, resulting in more efficient and effective learning. Furthermore, Rothkopf (1976) indicated, that adjunct questions were intended to serve a similar purpose. These adjunct questions can either be embedded activators, or on occasions, they can be a detached strategy.

2.3.1 (b) Structural relationships

Our learning environment still relies heavily on text based instructional materials (Ramsden, 1992). Consideration, therefore, needs to be given by instructional designers to the cognitive process of reading comprehension, and the variables in both the reader and the text, that affect the learning process (Stewart, 1988). He identified these variables as intrinsic learning characteristics that were inherent to learners, including:

1) purpose
2) world knowledge
3) cognitive and meta-cognitive skills
4) imagery ability

Instructional designers should be concerned with linguistic factors when involved with text design (Stewart, 1988). Research on typographical cueing has found that if headings in text are chosen and arranged spatially and typographically to reflect the structural relationships in the text, comprehension of both the structure and the content will be enhanced (Stewart, 1988). Therefore, improving the correspondence
between an individual’s conceptual map, and the typographical organization of a heading, brings together verbal and visual cueing, combined with the typography to enhance comprehension of both the structure and content of the text. Therefore, consideration should be given to the use of graphical organizers which encourage the reader to utilize their imagery abilities (Stewart, 1988).

However, the way text is comprehended and remembered is a function of both the structure of the text, and the individual’s knowledge utilization skills (Voss & Bisanz, 1985). Comprehension of instructional material involves a dynamic set of cognitive processes. There was a common belief that meaning lies on a page to be automatically lifted into the minds of learners (Cunningham & Broden, 1990; Stewart, 1988). Comprehension of learning materials was facilitated through an interplay between an individual’s meta-cognitive control processes, which manage the interaction of a top-down (text-based) cognitive processing, and a bottom-up (knowledge-based) cognitive processing (Spiro & Meyers, 1984). Information in an individual’s permanent memory is highly organized (Winne, 1985). The one way of describing this was to identify three basic theoretical forms of information:

1) concept
2) proposition
3) schema

These forms of information achieved meaning by their relationships to one another; learners are able to learn better from text when they can follow the organization (content and structure), and later use that organization (Brandt, 1978).

Research into text design has revealed that text design which supports each of the component comprehension processes, like identifying important ideas in text, organizing those ideas and integrating them with prior knowledge, improves comprehension and recall of text information (Glynn & Britton, 1984).

However:

It will be possible to show that an instructional strategy, which consists only of textual representation, cannot be as effective as text-plus-graphics, for certain cognitive style combinations.

Organization of text can be made explicit through both verbal and typographical cueing systems (Rosch, 1975-b; Glynn & Britton, 1984). Consequently, advance organizers (Ausubel, 1962) should state in advance of reading, that high-level learning was the instructional outcome, and should lead the reader to adopt a deep approach (Dahlgren, 1984) to the reading of a passage. Stewart (1988) proposed a
principle of textual structure and organization, which deduces that if the critical information to be communicated is appropriately emphasised as part of an overall text structure, comprehension will be facilitated.

2.3.2 Visual representation

The same kind of misconception exists with the use of visuals, as with text in learning. There is an expectancy that the message is implied naturally within the visual (Perkins, 1980) and that it will automatically be lifted into the mind of the learner. This was a common misconception of the power of most mnemonic systems (Levin, 1981-b). Although exploded drawings (Merrill et al., 1992) are useful as visual instructional strategies for explaining complex attributes of some types of concepts, before using this technique, the designer should ensure the exploded diagram isolates the critical attributes.

The message was actually constructed in an interaction between the visual stimuli and the prior knowledge of the viewer (Stewart, 1988). Too much emphasis has been placed on the role of the visual, and not enough emphasis has been placed on the internal processing of the viewer in educational settings (Winn, 1982-a; Salomon, 1985; Stewart, 1988). However, the more detail present in the image, the more features must have been activated to produce it, and the more extensive the resultant memory would be (Kosslyn, 1975).

Ritchey & Beal (1980) have reported their results in terms of within-item and between-item encoding elaboration, as well as the effect of these types of elaboration on retrieval strategies. Their results showed that the use of an imagery task, did serve as an effective means of manipulating elaboration, while permitting collection of incidental recall. They were able to demonstrate their pattern of results were consistent with the conceptualization of elaborative processing in semantic memory. Furthermore, the Ritchey & Beal (1980) results also suggested, that different relative levels of between-item and within-item elaboration may mediate the use of different retrieval strategies. They called for further research into the encoding and retrieval processes.

The findings from this research will be reported on in terms of the same within-item and between-item elaborations to emphasize the differences in the information processing requirements (see Chapter Seven: Meta-Knowledge Acquisition Process, sub-section 1.5 Computer-Programming Concepts as Analogic Knowledge Elements).
High imagery is an ability to represent both verbal and nonverbal visual cues in memory, and to retrieve either equally well (Ernest & Paivio, 1969). They were able to show that performance on objective spatial tasks, which reflected the ability to transform (in their participants' imagination) figural information, was predictive of visual memory in certain situations.

Researchers were engaged in debate over the issue of whether visual information is processed as picture-like images or word-like propositions (Fleming, 1977; Ernest & Paivio, 1971; Winn, 1982-a). Therefore, the issues which impact on the ways an individual processes visual information are (Winn, 1982-a):

1) nature of the learning task
2) processing levels required
3) degree of translation from one form of information to another
4) competencies of the learner

The stance taken by Winn (1982-a), was to support the contention that visual information can be processed propositionally. This body of research is known as the Schema Theory. It was proposed that propositions representing knowledge, were stored in the form of schemata (Winne, 1985). Similar constructs have been identified as frames by Minsky (1975).

Winn (1982-a) identified three visual cognitive processes:

1) perceptual
2) assimilative
3) analogical

Investigations of the relationship between cognitive tasks and preference for representational mode have been reported by Riding & Ashmore (1980); Riding & Dyer (1980); and Riding & Calvey (1981). Due to a lack of evidence elsewhere, these studies may not hold over time (Riding & Rayner, 1998).

This research extends the investigations on the effects of cognitive style construct and instructional format by devising special instructional strategies for complex programming concepts.

2.4 Learning Content Structure: Automated Concept Formation

Representation of defined (abstract) concepts is difficult, as they cannot readily be seen. This is of particular importance when considering the interactive effects of the cognitive style construct on learning ability. For instance: Wholists may not be able to locate fine
detail easily, while the Analytics may have difficulty correctly identifying the complete concept (Riding & Rayner, 1998).

Furthermore, there was an issue of fidelity, according to Merrill (see Reigeluth, 1983). He asserted that there should be a degree of correspondence between the:

1) actual object
2) event
3) symbol and its representation

The representation should usually include all of these defining characteristics that make the object or event a member of a particular class. For instance: if a mammal were defined as a fur-bearing animal that suckles its young, then it may not be sufficient to indicate that a cat was a mammal (Garner, 1974; Rosch, 1978).

Millward (1980) discussed four major models for concept formation. These models were:

1) prototype .. (Bartlett, 1967; Posner & Keele, 1968)
2) exemplar .. (Bransford & Franks, 1971)
3) frequency .. (Neumann, 1977)
4) rule models .. (Rosch & Mervis, 1975)

It has been shown previously (in Chapter Two: Conceptual Framework, section 2. Concept Learning), that the research into concept formation has been limited to the particular researcher's paradigm, when a more inclusive stance should be taken. Therefore, the Computational Theory of Concept Formation proposed by Nelson (1977) should serve to integrate the facts from different fields of research. This theory was broadly based in the disciplines of human information processing (semantic memory), and artificial intelligence.

The Computational Theory is based on research from:

1) Norman & Rumelhart's (1975) MEMOD-system (a computer implementation in the study of language comprehension and question answering, perception and problem solving, and a reasoning and question answering system)
2) Anderson's (1976) Adaptive Control of Thought (ACT) theory of cognitive architecture, for an automated learning production system.

This is a complicated system, in which facts encoded as propositions (declarative knowledge), are compiled into a procedural form, and undergo continual refinement. The Anderson (1976; 1983) learning system incorporated the rather human-like fact retrieval behaviour of spreading activation. This phenomenon occurs when the initial facts produce a spread of logic-flow, as new symbols enter short-term memory nodes, causing the system's semantic network to continually increase in size (Langley & Jones, 1988).
While these newer learning systems are currently in a developmental phase, they appear to have no means by which to accommodate differences in cognitive style.

Therefore:

*the Meta-Knowledge Processing Model proposed in this research initiates an entirely new technological approach to concept attainment.*

3. Retention and Instructional Strategy

Programming concepts have been discussed earlier, as being largely abstract in nature. As such, the control (or logic flow) structures of a programming language are difficult concepts for novice learners to absorb, or transfer to a new situation.

*These abstract concepts are presented in verbal exposition statements (see Figure:3.9). The learners' ability to demonstrate their understanding of these concepts was assessed.*

Knowledge subsumption is a cognitive process involved in learning and forgetting (Ausubel, 1962). He described a model of cognitive organization that also resembles the Rosch (1978) principles of categorization. However, in this model he inferred that a cognitive structure was organized in an hierarchical manner, with highly inclusive conceptual traces. He used these traces to describe the continuing representation of past experience and present cognitive structure, as being purely hypothetical constructs only. Furthermore, he proposed that new material was subsumed under a relevant and more inclusive conceptual system (Rosch, Mervis, Gray, Johnson & Boyes-Bream, 1976), which functions as an anchoring process to facilitate retention.

However, structured instructional strategies that only focus on specific skills promote short-term retention only (Bagley, 1990). She proposed that if the instructional goal is long-term retention (like remembering how to apply or use a newly learned concept in a different situation); structured instruction should focus on developing *schemata* of conceptual or procedural skills.
Retention and Instructional Strategy

The ability to follow programming logic relies on well-developed conceptual skills. Conceptual processing is grounded in perception, for both perceptual similarity and abstract rules (Goldstone & Barsalou, 1998). Therefore, instructional materials should encourage the learner to participate in worked examples (with provided suggested solutions).

This research has developed instructional strategies, which promote long-term retention, especially when the amount of assistance is gradually faded during the execution of each worked example (Merrill et al., 1992).

The discussion now turns to the relationship between retention, cognitive style and instructional strategy. Unfortunately, there is no evidence of research conducted on this aspect of human learning behaviour, specifically for programming concept acquisition.

3.1 Relating Memory Structures to Cognitive Style

Four kinds of memory structures have been identified by Gagne & White (1978), and investigated by Arzi, Ben-Zvi & Ganiel (1986), in a longitudinal study of retention of science learning. These memory structures were:

1) networks of propositions
2) intellectual skills
3) images
4) episodes

The processing of images and episodes is often a laissez-fair approach, compared with the instruction for propositions and intellectual skills. The normal practice of questioning following an instructional event, such as the presentation of films and demonstrations, does not directly influence the formation of images (Arzi et al., 1986). Although it may be helpful in linking image and propositional networks; it is important to encourage learners to draw diagrams or rough sketches, to encourage them to paraphrase an instructor's diagram, much in the same manner as learners are often asked to paraphrase sentences, to encourage the processing of propositions (Gagne & White, 1978).

The issue of questionable subjectivity was raised by Riding & Read (1996), in relation to data collection methodologies of students' learning habits. However, they believed there was an important connection between cognitive style and its relationship to behaviour (Riding, 1997).

Visual images and pictures in which objects are interacting, produce greater recall than when the objects are depicted separately. In the past, research on memory has been conducted in highly controlled, experimental laboratories (Baine, 1986). Models were developed comprising hypothetical structures and processes to explain observations made
during experimentation. As models failed to fulfil the predictive expectations, they were modified or replaced by a new model, which had been developed to fit the evidence (Baine, 1986).

Differences in retention should be attributed to degrees of stimulus elaboration, rather than to differences in depth of processing (Craik & Tulving, 1975). Certain kinds of elaboration increased memorability more than other kinds. Therefore, elaboration that merely adds to what must be learned, does not increase the memorability of the other material, and often decreased it. However, elaboration that increases the amount of other material that can be encoded using already learned schemata, is beneficial to learning (Wickelgren, 1981).

4. Building Electronic Learning Systems

Technology now provides the means to produce individualised instructional packages with relative ease. Multimedia and Web courseware development accentuate a highly graphical (or visual) approach to instructional formats. For instance: Ziems & Neumann (1997) used Multimedia Toolbook to develop interactive exercises and rule-based diagnosis components of an educational system. Although most electronic courseware may allow the user to proceed at their own pace, the majority of designers still assume, that to facilitate learning, all users will eventually assimilate the graphical material with their current knowledge. There is little or no consideration for different cognitive styles.

This dissertation is working towards the feasibility of an electronic learning system, which employs the use of the CSA as a screening tool (see Chapter Two: 4.3.3) to direct learners to the appropriate instructional format for their cognitive style.

It is difficult to reach a consensus for understanding how humans process information. Technology drives one group of researchers to pursue the notion of creating artificial intelligence, as a means to replicate the information processing capabilities of the human mind. There are unsettling explanations about human information processing, which completely refute the traditionalist approach (Jenkins, 1980). Some depict memory as a segmented entity represented in a systems-like structure chart (Tennyson & Spector, 1998). Others support the notion that external considerations from the environment affect the information processing operations of the human mind (Winn, 1981; Baddeley, 1982; Baine, 1986).
However, there are other researchers who proposed a purely internal orientation, in which the human mind is depicted in a mechanistic manner as a closed processing system, receiving continual input from the world around us, and drawing on isolated sensory data, which is processed in a highly organized fashion (Lindsay & Normon, 1977).

Research, which provides technological solutions to instructional science, is now discussed in sub-sections, including:

- Attaining an information super-highway
- Theoretical learning systems
- Capturing the learning environment
- Identifying learners' skill levels
- Constructivist learning approach
- Automated knowledge acquisition
- Computer aided instruction

4.1 Attaining an Information Super-Highway

The physical global linking of individuals, via communications technology, now provides us with the capabilities of instant access to information, and effective electronic learning systems. So far, the notion of an information superhighway as described by the DFE (1995) remains a purely theoretical exercise. To date there is no evidence, which suggests the building of such a system exists. Riding & Rayner (1995; 1998), however, proposed integrated learning systems that can act as intelligent tutors. They argued for these systems to have the capacity for assessing cognitive style.

However, instructional science has commenced assisting with electronic courseware design. Merrill (1987) described a new Component Design Theory (CDT) which includes the Reigeluth Elaboration Theory. Merrill et al. (1991) have also presented a series of papers to describe their Instructional Transactions Theory (ITT). (See this chapter, sub-section 1.1.2 Making new knowledge meaningful, for the description of CDT.)

4.2 Theoretical Learning Systems

Theoretical examples of computerized learning environments, such as the Knowledge-based Instructional System Design (KISD) methodology (Duchastel, 1991); adopted a systems design approach, which concentrated on knowledge relationships and learning context. Tennyson (1993) has proposed the Minnesota Adaptive Instructional System (MAIS). He suggested it links knowledge acquisition (declarative, procedural and contextual) to expository learning, practice and problem oriented strategies. Furthermore, his system also links the cognitive
processes of recall, problem solving, and creativity to a complex system of self-directed learning strategies. McAlpine & Weston (1994) discussed a comprehensive list of attributes of instructional materials. They identified a new instructional category that emerged from the learning content not previously described in the literature (McAlpine & Weston, 1994:21).

“Language was created through the recognition that certain attributes did not fit their understanding of the content category. Validation for this aspect took place "when the definition for the previous content category was revised; it had by definition grouped language attributes with content attributes”

They renamed their content category, subject matter, to clarify the distinction between language and content.

Bobrow & Norman (1975) argued that an automatic generation of analogical or memory matches was possible, through a context-dependent, description passing process. They suggested that the retrieval mechanism must be intelligent enough to combine both descriptions and context in a meaningful and useful manner. Although, the processing structure of the human memory system was limited in terms of data or resources, they discussed the notions of top-down (conceptual) and bottom-up (data) processing, and proposed that a high-level mechanism should guide the human conceptual processing, taking into consideration the motivation and purposes of an individual.

4.3 Capturing the Learning Environment

Plass, Chun, Mayer & Leutner (1998) are amongst the growing number of researchers working with electronic courseware development. They are producing a multimedia system, which instructs for a second-language. Their new system supported visual and verbal learning preferences. Yost, Vareeka & Marefat (1997), are developing a visualization system, which they proposed as an active-agent, which has the capability to solve problems by extracting interesting data for spatial and temporal understanding. Montazemi & Gupta (1997) interests lie with the measurement of cognitive feedback from an interface agent.

Much is known about capturing the learning environment. For instance: in relation to computer interface design, Merrill et al. (1992) suggested that the learning concept referent may not necessarily be present. However, there must be some correspondence between the representation of the concept-to-be-learned, and the attributes of the referent. While the symbolic form describes the referent via words, there may be no correspondence between the referent symbol and its attributes (Merrill et al., 1992).
They explained the first procedure in analyzing a content area is to determine the relationships between concepts. There are two types of concept taxonomic structures: *kinds of* (an x is a kind of y); and *parts of* (x is part of y). Concepts within the taxonomy, can be structured according to superordinate, coordinate and subordinate relationships to one another.

However, a *concept taxonomy* should not be confused with a *task* (or objectives) *hierarchy*, say Merrill et al. (1992). There was no implication of prerequisite task relationships in a *concept taxonomy*. It was possible to segregate and instruct a coordinate set of concepts from the middle of the taxonomy, without teaching the subordinate or superordinate concepts. Developing the *concept taxonomy* provided a more precise identification of the attributes of each concept class.

*Mental constructs* at the *fully functional level* (Klausemeier & Sipple, 1980), include perceptible and non-perceptible attributes of the concept, and the cultural meaning given to the concept name.

There are rules associated with *divergent examples* (Merrill et al., 1992); concept classification performance should be promoted by exposing the learner to examples of the target concept that were as divergent as possible. Examples are divergent when there are wide differences among presentations of their critical attributes. Furthermore, convergent examples should not be used in a concept lesson (Merrill et al., 1992).

### 4.4 Identify Learner Skill Levels

Concept classification performance can be achieved by using *attention-focussing devices* to direct the learner's attention. The critical attributes present a specific example and correct for under-generalization errors. To correct for misconception errors (Riding & Wigley, 1997), potentially confusing attributes can be presented in particular examples or non-examples. The absence of the critical attributes in a specific non-example is designed to correct for over-generalization errors (Merrill et al., 1992). They usually referred to this phenomenon as developing skills, while the transfer of principles and attitudes were represented as *general ideas*. They described a twofold problem of how to construct curricula that can be taught by ordinary teachers to ordinary students.

The first issue was how to keep the instructional materials focussed? Secondly, how to match the instructional outcomes of instructional material to the differing abilities of learners at different school levels?
Chapter Three: Literature Review

However, the importance of discovery as an aid to teaching was explained by Merrill et al., (1992:20) as:

"A student must develop an attitude toward learning and inquiry, guessing and hunches, and the possibility of solving problems on one’s own as vital to gaining mastery of the fundamental ideas of a field"

4.5 Constructivist Learning Approach

The concept of active learning is central to the constructivistic approach to learning.

The learning environment has five facets (Perkins, 1991):

1) information bank
2) symbol pads
3) construction kits
4) phenomenaria
5) task managers

Perkins used these learning environment categories as a grid to show the relationship between information processing technologies and instructional process:

1) Information banks: the explicit information for the topic-to-be-learned
2) Symbol pads: the devices a learner will use to support their short-term memory while learning
3) Construction kits: the physical building resources
4) Phenomenaria: are the variety of contexts used to situate the topic-to-be -learned
5) Task managers: can be either textual or instructions from a teacher

Therefore, phenomenaria and construction kits were the two learning environment categories, which actually situate the topic-to-be-learned in authentically complex and meaningful contexts. In other words, the learner is engaged in an active manner while learning the topic (Perkins, 1991).

4.6 Knowledge Acquisition

Gordon, Schmierer & Gill (1993) described the empirical validation of a knowledge acquisition methodology using conceptual graph analysis for instructional system's design. They suggested that conceptual graphs were a representational medium, which could be used to integrate and organize knowledge obtained from:

1) documents
2) verbal protocols
3) question probes
4) observation of task performance
They validated this method by presenting two groups of learners with text and graphics on a topic in engineering dynamics.

One set of materials was written by a recognized subject matter expert (expert-generated text), and subjected to conceptual graph analysis. The text was first translated into a conceptual graph structure, next the graph was revised via question probes and observation/induction methods. The final graph was then returned to a standard text format. Learners receiving the knowledge-engineered text solved significantly more problems than learners receiving the original text.

Conceptual graph analysis was a generalised method that can be used for a broad range of training domains, providing a highly structured means for making explicit the knowledge base to be incorporated into instructional design (Gordon et al., 1993).

However, the most comprehensive and effective way to teach people how to use computers according to Presno (1997), was to follow Bruner's framework. This framework consists of:

1) action: for enactments and demonstration
2) icons: for summarizing pictures
3) symbols: for words and numbers

4.7 Computer Aided Instruction (CAI)

The traditional instructional design view in the literature, appears to have completed a full circle, with an introduction of the technological solutions proposed for Computer-Based-Training (CBT). A powerful design approach already exists for generating rule-based instruction, particularly for CAI (Schmid & Gerlach, 1990). Although there is no mention of individual learning characteristics (cognitive style) Quealy & Langen-Fox (1998) investigated attributes of CAI delivery. They used:

1) text and still image
2) text, still image and audio track of the text
3) video image and audio track of the text

Technology can offer the effectiveness of learning strategies, whereby the learner has control over their learning environment (Tessmer & Jonassen, 1988). This means that the learner can have control over the method for processing and recall of their knowledge, during an instructional event. Technology in the CAI environment, forces the learner to adopt a generalized set of mental skills, as opposed to the development of reactions (cognitive strategies), to the instructional strategies they experience, when interacting with the more traditional types of instructional materials.

Tessmer & Jonassen (1988) proposed that although teachers will, and should, design their own software, teachers should not have to learn programming to do so (Lee, 1994). They found that
novice learners participating in CAI benefit from working through a textual workbook before entering code into the computer. The biggest difficulty learners encountered was distinguishing the proper instructional outcomes (rules vs concepts and rules vs problem solving).

Other features of their approach were:

1) to ensure explanatory feedback is provided with the right answers
2) use of individualized learning strategies as an option for tutorial programs
3) an emphasis on verbal information in the CAI lessons and a preference for text approach

The problem of how to tackle explanatory feedback was also an issue which arose with the Hank language (Collins & Fung, 1999).

4.7.1 Computer Based Training (CBT) Authoring Tools

There are a number of fledgling CBT systems described in the literature:

Muraida & Spector (1992-93) have designed an Advanced Instructional Advisor (AIDA), which automates instructional design, for use by Air Force technical training specialists.

Nkambou, Frasson & Gauthier (1998) have presented an object-oriented Intelligent Tutoring System (ITS), for delivery of curriculum and courseware. Their system is called Curriculum Representation and Acquisition Model (CREAM). This system consists of, a set of tools, which enable a courseware designer to create and edit educational programs. However, it is a courseware generation kit, which follows instructional science tenets, and as such, allows the specifying of target public and course description modules.

Murray (1998) has devised a meta-authoring tool called Econ. It is a domain independent collection of tools, for authoring all aspects of a knowledge-based tutoring system, comprising: content development tools, instructional strategy components, a student model, and an interface design module.

Tennyson & Spector (1998) have outlined a courseware development model, in which software products and system dynamics combine to provide a learning laboratory for courseware developers.

However, all these courseware environments are complicated and difficult to manage. Consequently, ID2 have produced products (ID Expert and IDXelerator) focussing on efficient and effective instructional developmental tools (Merrill, 1997; Merrill, 1998; Merrill & Thompson, 1998; and Merrill & ID2 Research Group, 1998). These products
have been designed to equip the courseware designer with correct (instructional science) designing tools. Instructional development and evaluation involves three phases (Merrill et al., 1992):

1) design
2) production
3) evaluation

There are three major approaches towards these phases (Merrill et al., 1992):

1) artistic
2) empirical
3) analytic

While each approach has certain merits, there are clear disadvantages associated with two of the approaches. Merrill (1992) has described them as the artistic and analytic; because they become expensive to implement, and/or are based on trial-and-error, leading to a hit-or-miss outcome, which often overlooks effective alternative methods. He therefore proposed a prescriptive model of instructional science, which divides all variables of concern to instructional scientists, into four classes:

1) instructional situation
2) subject matter
3) instructional strategy
4) instructional outcome

It is these Merrill variables of concern, which form the instructional science platform for this research.

Furthermore:

The ID₂ courseware will be used to develop the learning system discussed in this dissertation.
Summary

This chapter commenced by reviewing knowledge acquisition theories pertaining to abstract concept acquisition, and in particular mechanisms individuals use to access previously stored experiences. The review was divided into discrete sections, thereby providing adequate coverage, with enough depth to establish a well-grounded foundation to support the planned in-depth data analysis.

The first section investigated work involving knowledge acquisition, which focussed on the creative aspects of human intelligence. Views on the differences in cognitive style introduced the notion of the cognitive style construct (Riding & Cheema, 1991). This construct provides plausible explanations for making a distinction between how we think about what we see, as opposed to the our inherent mode of processing information.

The second section of the literature review, concentrated on the instructional design issues surrounding instructional format. Within this section, various mechanisms were put forward to explain our information processing strategies to highlight the complexities relating to visual (picture or graphics) formats, and verbal (text-only) representations. The most significant contribution that is relevant to this research project comes from the work on notational symbol systems described by Goodman (1968).

The third section gave a brief description of a very substantial body of literature relating to memory retention and transfer. However, as the main focus of this dissertation is the relationship between the effects of individual perceptions of instructional strategies on the acquisition of particular types of process concepts, this valuable research was not presented in any depth.

The final section of this chapter, dealt with some of the issues that are surfacing through the pursuit of electronic courseware. Once again, as this dissertation concentrates on the strategic context of attaining a meta-knowledge modelling tool, the examples were limited to briefly provide a sample of the current state of play.

The next chapter examines in depth, the complex issues relating to this strategic knowledge context, to highlight the importance of correctly describing how an individual fits into the larger scheme of learning and instruction.
As mentioned in previous chapters, this research is a synthesis of several disparate research disciplines. Consequently, by drawing on the valuable contributions made by earlier researchers, it is now possible to isolate the strategic research variables. This is a complex melding process, as it involves defining variables that have multiple points of origin (see Figure:4.1). Chapter Two : Conceptual Framework, reviewed work from the *instructional science* and *information processing* research paradigms to provide the primary context for this investigation. Chapter Three : Literature Review, presented a general overview of a more general body of literature, which focussed on endeavours to combine *cognition* and *instructional strategies*. This chapter now isolates the most important research variable, which is critical to this dissertation; namely, this is the *conditions-of-the-learner* (Reigeluth,1983-b), as it describes the various *learning states* of an individual.

However, *conditions of learning* should not be confused with *instructional conditions* (Aronson & Briggs, in Reigeluth,1983-b). Therefore, a brief discussion on *instructional conditions* is given to orient the reader. *Instructional conditions* are the instructional components designers refer to when organizing learning content/materials. The more important of these *instructional conditions* were reviewed extensively in the previous chapter, section 2. (Instructional Format).

This chapter, is therefore, divided into three sections:

- **Instructional conditions**
- **Context of conditions**
- **Interactive effect of the internal/external conditions-of-the-learner**
1. Instructional Conditions

The proposed meta-knowledge processing model (Figure:4.1), includes a type of instructional agent (see Figure:4.2), which interacts with the Reigeluth instructional conditions component.

There are three major components of a theory of instruction (Reigeluth,1983-b):

1) methods
2) conditions
3) outcomes

The theoretical context for these components are depicted in Figure:4.2.

Methods are the different ways to achieve different learning outcomes under different conditions. For instance: methods can take the form of an instructional agent (maybe a teacher, or some other instructional medium), that directs its actions at a learner (Lander, in Reigeluth,1983-b).
Conditions are the factors that influence the effects of the instructional methods employed, and as such are important for prescribing instructional strategies. Instructional conditions have a two-fold impact (Reigeluth, 1983-b). Firstly, designers may be able to manipulate them as some conditions interact with the method to influence their relative effectiveness (like: instructional format). Secondly, there are instructional conditions that cannot be manipulated, and therefore are beyond the control of the designer (like: learner characteristics). In fact, instructional theories and models specify the conditions under which each set of method variables should or should not be used.

This research identifies benchmark performance levels for the acquisition of basic programming knowledge. Consequently, it will be possible to target for the measurable instructional outcomes.

Outcomes are the various effects that provide a measure of value of alternative methods under different conditions, as they focus on instruction rather than on the learner (Reigeluth, 1983-b).
Learner-outcomes are just one aspect of instructional outcome; others include:

1) **effectiveness**: broken down into various kinds of learner achievement
2) **generic knowledge**: problem-solving ability, discover relationships, and reason logically
3) **content-specific knowledge**: the ability to recall particular facts, classify examples of specific concepts, and follow specific procedures

Lander (Reigluth, 1983-b) described these outcomes, as forming part of the wider instructional process, calling them *goals*. They may be particular psychological and behavioural characteristics developed by the learner, under certain internal and external instructional conditions. Reigeluth (1983-b) argued further, that as *instructional conditions* and *methods* are not fixed components, the *Aptitude-Treatment Interaction* (ATI) model (Holliday, Bruner & Donais, 1977) was only a special case model, because it ignored these other important kinds of instructional condition variables (for a full description of the ATI see Chapter Two: Conceptual Framework, section 1. Instructional Science Paradigm).

Moreover, Reigeluth (1983-b) proposed that instructional design theory must include:

1) **instructional model(s)**
2) **a set of conditions**: to specify the context for each model
3) **the desired or actual outcomes**: for each model with specified context

### 2. Context of Conditions

In specifying individuality in learners, the literature often fails to distinguish between *instructional conditions* and the *conditions-of-the-learner*. According to Aronson & Briggs, (In Reigeluth, 1983-b:98) the *conditions-of-the-learner* are:

"those internal states and external events that together are required for learning to occur. ........are motivational states and mechanisms involved in processing, storing, and retrieving information"

This section describes the close interactive relationship between an individual's capacity for dealing with the complex nature of the *internal- and external- event-conditions* (Figure:4.3).
Internal-conditions are those states within the learner that are involved in learning (they are described more fully in sub-section 2.1 of this current chapter).

They represent an individual's:

1) **motivational state**: possessing a suitable attitude for learning

2) **memory capacity**: mechanisms involved in processing, storing, and retrieving information

Cognitive strategy acquisition (like: recalling relevant concepts and rules), is based on prior learning of intellectual skills. Whereas verbal information acquisition (like: recalling the larger meaningful context), is facilitated if the novice learner can recall previous learning, that is related to their prototype of the new concept (Aronson & Briggs in Reigeluth, 1983-b). See Chapter Two: Conceptual Framework, topic 4.1.2 Cognitive strategies.

External-conditions (such as gaining a prerequisite skill, or attending a lecture), are those events occurring outside of the learner, that activate and support the internal processes of learning (Aronson & Briggs in Reigeluth, 1983-b) (they are described more fully elsewhere in this chapter, see sub-section 2.2 below). Novice learners must have the opportunity to practice, thereby learning how to correctly distinguish between examples and non-examples.

The relationship between internal- and external-conditions-of-the-learner is complex. For instance: with intellectual skill development, it requires both the previously learned prerequisite skills to be recalled, as well as the stating of specific rules. In the case of attitudinal skills, they are the ability to recall a model that exhibits the appropriate attitude (like: recalling relevant
facts and intellectual skills (internal-) for assessment/demonstration (external-) ). In
addition, immediate feedback is essential in motor skill development.

External events provide the framework for planning instruction.

It is therefore appropriate that this research explores the interactive effects
of matching instructional format and the cognitive style construct.

Furthermore, the various types of learning are distinguished from one another by the fact
that different sets of conditions are needed for each type of learning to occur (Aronson &
Briggs in Reigeluth,1983-b).

Consequently, it may be concluded that effective and efficient instructional
strategies must cater for additional features of a learner's external-
conditions.

They include:

1) prerequisite learning: to establish entry level skills for particular
   learning modules
2) instructional sequencing and event issues: to ensure continuity of skill
development
3) the interaction of learner characteristics and media

2.1 Internal Conditions

The term internal-conditions refers to the process of gaining a skill and the subsequent
storage (committing to memory) of prior capabilities, that are supportive of further learning.
The topics discussed in this sub-section include:

- Memory capacity
- Gagne's capability categories

2.1.1 Memory capacity

There are many examples of outstanding work relating to the functioning of human
memory. However, there are no accounts that connect computer-human interaction,
instructional strategies, and cognitive performance benchmarks.

Therefore, the proposed meta-knowledge processing model breaks new
ground.
To identify those states within the learner, that facilitate learning, the next sub-topics include:

- Memory research
- Thinking skills
- Relationship of instructional format and cognitive style
- Representation of information during thinking
- Mode of processing information

2.1.1 (a) Memory research

In the past, research could not produce sufficient evidence to explain how the human mind functions. Some have said there was simply not enough evidence to test the hypothesis, that two hemispheres control radically different styles of thought; and that some individuals may be dominated by one hemisphere, producing different thought patterns from other individuals. These hypotheses are sheer speculation (Lindsay & Norman, 1977). Since then, Baddeley (1982; 1990) has written several books and many papers on human memory. He said that human memory was a collection of interacting systems (Kosslyn, 1987; 1995), which combine to store and subsequently retrieve information.

Riding, Glass & Douglas (1993) concurred. They have extended the memory research paradigm. They proposed that different people process the same information in different ways, by using different areas of the brain, during thinking and decision making. It is probable that these processing styles have an underlying cerebral basis, and are therefore likely to be related to cerebral orientation (Riding et al., 1993). The specialisation of one cerebral hemisphere, for verbal function, and the other for visuo-spatial, has been long established (Kosslyn, 1980; Levie & Lentz, 1982).

Evidence is accumulating on how complex human perception is. For instance: our mode of processing information is unrelated to our representation of information during thinking (Riding & Rayner, 1998). They suggested that identifying the exact locations of where this processing occurs, is likely to be different from simply right or left hemispheric specialisation. Moreover, the mechanisms by which cognitive styles are made operational, is not clear.

However, Levy (1990) argued for the existence of meta-controlling programmes in the brain. He believed that they can allocate processing to, and selectively activate,
specific functional systems in the cerebral hemispheres, and must be considered when attempting to explain individual performance.

Nevertheless, Witkin, Moore, Goodenough & Cox (1977), were not sure how far it is possible for individuals to change their cognitive style. Furthermore, they proposed that some individuals may not take equally well to a new style, and warn that educators need to develop the diversity in behaviours, within individuals, as being as important an objective, as acknowledging the utilization of diversity among individuals.

2.1.1 (a) (i) Memory models

Over time, a number of memory models have been put forward. Two such models depict a mono- or dual-framework. Rosinski, Pellegrino & Siegel (1977) have argued that for a single memory system, verbal access times decrease more than pictorial access times; as opposed to simultaneous representation in a verbal and non-verbal memory system. They proposed that verbal access to a single semantic system was more rapid.

If semantic decisions regarding verbal material are made in a non-verbal system, then one was led to question the function of a verbal-memory system (Rosinski et al., 1977). They proposed that a further dual-memory model could potentially account for their present data, and assumed that category decisions were made in a verbal-memory system. Such a model must also reflect differences in access time, between pictures and words, large enough to compensate for the necessary transfer time required for pictures to gain access to the verbal-knowledge system (Rosinski et al., 1977). They hypothesized that access and transfer times, can be summed, to yield a measure of access time into semantic memory, and that this is functionally equivalent to a single-memory model. Therefore, they considered the processing differences between pictures and words as estimates of access times, related to a single-semantic memory.

A single memory system seems more plausible when reviewing the research profile, which is emerging in the more recent literature. For instance: Kosslyn (1987) proposed, that the standard view that imagery as a right hemisphere phenomenon is incorrect. It may only be that it is more important for that hemisphere. Then Kosslyn (1988) argued, that objects were constructed in our minds, one piece at a time. Furthermore, Kosslyn, Malikjovic, Zhamilton, Horwitz & Thompson (1988) showed that visual mental images can be generated by either left or right cerebral hemispheres, but in different ways.
While Kosslyn (1995) stated the view that there are two ways to form images by:

1) retaining perceptual input
2) activating information in long-term memory

2.1.1 (b) Thinking skills

Because of the abstract nature of programming concepts, they often need to be expressed as analogies. Therefore, the basic information processes in analogical reasoning are (Sternberg, 1977):

1) translating the analogy into an internal representation on which to perform other mental operations
2) generating the response to complete an analogy solution

He argued that inference, mapping, and application, as well as encoding and response, are all intermediate comparison operations used in analogy solutions. Anecdotal evidence suggested that novice-programmers are expected to map programming analogies to an internal-representation, devoid of instructional assistance.

This research expects to uncover an instructional strategy that assists with this difficult process.

The rush to embrace technological courseware, has reopened the pursuit of human perceptual processing. Franks & Bransford (1971) portrayed acquired memory representation in terms of a schema, which was composed of a pattern pro-forma and transformations. While Palmer (1977) advocated that perceptual representations were selectively organized data structures.

The learning domain of computer-programming requires high-level thinking skills. Sternberg (1988) explained the notion of metaphorical thinking. He argued, that some imagine (or abstract) concepts, occur in the human mind in sets of local sub-spaces. Rosch (1978) described this event as the vertical dimension of categories. They may overlap, and according to Sternberg (1988) and Merrill, Tennyson & Posey (1992), it is possible to compute the conceptual distance between points within a given local sub-space, as well as compute the distance between sub-spaces.
2.1.1 (c) Relationship of instructional format to cognitive style

It is now known that individuals differ in the mode in which they represent information during learning (Riding & Calvey, 1981). This internal representation, affects the efficiency of learning and recall in performance. For that reason, they advocated that learning outcomes were best when the style and content of the instructional format matches the mode of representation in which the individual performs best (Ausburn & Ausburn, 1978). It has been said that Verbalizers learn best with text, and Imagers learn best with pictorial formats (Riding & Douglas, 1993). Nevertheless, these studies only test such hypotheses using the learning domains of reading and basic mathematics.

The issues relating to individual differences in the way we may process, store and retrieve information need more investigation.

This research expects to show individual differences in conceptual knowledge relating to the acquisition of complex programming processes, in terms of the interaction between the Riding cognitive style construct and instructional format.

2.1.1 (d) Mode of processing information

The literature reveals research which distinguishes human ability to process information, as a combination of mode of processing information, and the way we represent information during thinking (Riding & Mathias, 1991). Different theorists make their own distinctions on individual's cognitive differences (Riding & Cheema, 1991). The naming of their Wholist-Analytic continuum, for example, maps to cognitive categories used by other researchers. For a description of these cognitive style continua see Chapter Two : Conceptual Framework, topic 4.1.1 Cognitive style construct.

These well known terms are used frequently throughout the literature in a number of different research disciplines:

1) levellers-sharpeners Holzman & Klein (1954)
2) field dependence-field independence Witkin, Dyke, Patterson, Goodman & Kemp (1962)
3) impulsive-reflective Kagan (1965)
4) divergers-convergers Guilford (1967)
5) holists-serialists Pask & Scott (1972)
6) wholist-analytic Riding & Cheema (1991)
The author believes that the literature may mistake the actual mode of processing information with the natural mode in which humans represent information during thinking. It is to the former dimension that most people refer, when describing verbal/imagery performance.

2.1.1 (e) Representing information during thinking
There is evidence of many new technological variables under investigation associated with this cognitive style continuum. The respective researchers believe, each one affects our capacity to learn effectively in a machine based learning environment. For instance:

1) ThinkerTools: a computer based learning system
   .. .. .. .. .. (Kozma, 1994)
2) Active-agents: capable of solving problems by extracting
   semantically interesting data for spatial understanding
   .. .. (Yost, Vareeka & Marefat, 1997)
3) Geneplore: a system, which models human cognitive processing
   .. .. (Finke, Ward & Smith, 1992)

However, none of these new technologies are capable of dealing effectively with the broad range of individual differences. Many complicated variables impact on the way we think. For instance, by comparing performance, with the recall of both concrete and abstract prose passages, a relationship was shown to exist between extraversion and involuntary verbal/imagery representation (Riding & Dyer, 1980).

2.1.2 Gagne's capability categories
There are many different skills associated with learning how to program.

This research measures the interaction of instructional strategies and cognitive performance on the acquisition of complex-programming concepts (expressed as an external-condition). Subsequently, the Gagne learning outcome categories provide a sound framework, on which to discuss the implications of the research results.
The five categories of learning outcomes (the Gagne (1985) capabilities), are now well known in the research community. They are discussed next, as separate sub-topics including:

1) intellectual skills
2) cognitive strategies
3) verbal information
4) motor skills
5) attitudes

He argued each type of learning capability is different. Subsequently, there is no reason for considering that they must be acquired in any particular order.

2.1.2 (a) Intellectual skills

Knowing how to program, involves many intellectual skills. For instance, to understand the concepts of logic patterns requires both declarative knowledge (know the rules), and procedural knowledge (problem solving strategies).

Our capacity to learn and remember has enabled us to develop tools, communication skills and technologies (Baddeley,1990). Consequently, symbols are used by humans as visual communication tools. Gagne (1985) argued that it is our intellectual skill, which makes this capability possible.

Nevertheless, instructional designers cannot be sure how individual learners will react to learning materials enhanced with symbols, added in an ad hoc manner. This dissertation attempts to unravel some of these issues.

It appears that clearer relationships between imagery and creativity variables emerge, when clear distinctions are made between those variables that examine (cognitive) preference, and those, which examine ability (Isaksen, Dorval & Kaufmann,1991-1992). They suggested there is a functional difference between preference and ability, and research designs. However, mixing these two types of variables produces unclear results.

As a consequence, there will be a clear separation of these variables for the data analysis.
2.1.2 (b) Cognitive strategies

Acquiring the *procedural knowledge* for writing new programs, requires integrating previous *procedural knowledge*, as for example, in identifying the sub-tasks involved in conditional looping techniques.

*Cognitive strategies*, are the means by which we regulate our own internal processes of attending, learning, remembering, and thinking (Gagne, 1985). There is evidence in the literature of mechanisms (*external-conditions*) to facilitate this (*internal-condition*) process. Schank (1975) provided an explanation of *metaphorical communication*. He explained that individuals cannot remember everything they hear (and see). As a result, their forgetting can be explained in terms of what the individual decided as crucial in the given instructional strategy, and what information can be easily rediscovered.

This process is defined here as, an *internal/external exchange process*. It is discussed below in sub-section 2.3.

Following, is a brief coverage of the issues relating to *cognitive strategy* development, including:

- prior learning of instructional strategies
- semantic memory
- age related differences
- information organizers
- absorbing the metaphor
- nature of internal representation

2.1.2 (b) (i) Prior learning of instructional strategies

Many of our daily tasks require us to use conditional logic. For instance, in choosing how much money to spend on an item of clothing. By the time we have reached adulthood, these *cognitive strategies* are usually well developed.

Consequently, this research taps into the *prior learning of these familiar strategies*.

*Cognitive strategies* are developed by memories of previous learning experiences involving our *intellectual skills* (Gagne, 1985; Aronson & Briggs, in Reigeluth, 1983-b). Schank (1975) described the process of understanding as the
connection of a causal sequence to an inference of remembered conceptualization, when assigned to new input conceptualization.

2.1.2 (b) (ii) Semantic memory

It is no wonder that developing instructional strategies for computerized abstract concepts is difficult. Cognitive strategies rely heavily on our capacity to remember. The nature of semantic memory is context dependent. This means that humans will see and remember the world, according to their previous experience. However, some will have more difficulty if their conceptualisation's are weak, or under-developed. For instance: Ritchey (1980) postulated, that when people read a word such as camel, in a sentence with the word zoo, then the memory portions of the extended representation appropriate to camels in zoos may be activated, although he could show no differences in recall between pictures and words, when categorized during input.

There was no reason to discard imagery as an explanatory construct in psychology (Kosslyn & Pomerantz, 1977). They questioned the manner in which images were thought of? Were they primitive, irreducible forms of representation, or derived from propositional representations? Unfortunately, he said that in the end, there may be no real answer to the speculation relating to what underpins imagery.


"researchers have adopted a theory of imagery in which images are conceptualized as mental pictures. If an image was like a picture, then more information could be extracted from a more vivid image. However, the experience of imagery as a picture may be phenomenal."

This research will show, that we should be asking questions about an individual's capacity to translate external non-notational (Goodman, 1968) representations (pictures) into internal notational structures.

2.1.2 (b) (iii) Age related differences

As we grow older, and continually experience more things, our cognitive strategies appear to streamline. One such strategy we develop is cognitive economy (Rosch & Mervis, 1975).
Notwithstanding research on effects of the aging process per se, there was no evidence relating to the effects of age on the acquisition of programming concepts. This learning domain is usually set in the secondary and tertiary educational sectors. Accordingly, the matter of visualization and age related studies, is of importance to this research.

For instance: Sternberg (1988) explained when younger, he could solve problems more easily in a verbal manner rather than rely upon his weak spatial skills. There is a considerable body of evidence, which shows differences in recall for pictures and words in adults (Paivio & Csapo, 1973; Sampson, 1970).

Most of the evidence on visualization has been collected using children, while a few others compare children and adults. Unfortunately, these studies are flawed, as they compare two groups of diverse prior learning capacities. For instance, Bransford & Johnson (1972) compared 10- and 11-year olds with university students. Children have been shown to differ from adults in terms of strategies applied to learning and organizing material (Ritchey, 1980; Brown, 1996).

However, there seems to be no reason to believe that the basic structural principles of semantic memory will change with age (Ritchey, 1980).

2.1.2 (b) (iv) Information organizers

One of the roles of cognitive strategies in the process of learning, is to facilitate the mind to attend. To a large extent, rememberings (Schank's (1975) causal chains) are tied up in one's personal experience with the world. Consequently, he argued that information is organized within episodic sequences, and these episodic sequences serve to organize understanding. Therefore, he called the simplest kind of episodic sequence that organises information, a script.

The instructional treatments for this research implemented graphical metaphors, a type of innovative scripting tool, to facilitate the acquisition of programming control structures (Figure:4.4).
The literature revealed a rare example of research that combines *the mode of processing information* with *the way we represent information during thinking*: Bezruyczko & Schroeder (1994) argued for fundamental differences between the visual preferences of artists, and nonartists, with interesting implications concerning the influence of art background on cognitive development. For some individuals, *thinking is seeing*. In fact, most people report they make an *image in their mind* of an object, when asked to describe a specific attribute of that object (Kosslyn, 1975).

2.1.2 (b) (v) Absorbing the metaphor

One of the independent variables used in this dissertation is the *instructional metaphor* (Figure:4.4). These metaphors have been designed to ignite the capacity to utilize prior learning.

Consequently, it was hypothesized that the *visual metaphor* delivery technique, will have an effect on the acquisition of complex programming concepts.

Ritchey (1980) posed the question; how do meaning representations develop? Furthermore, in calling for more work to be conducted using metaphor delivery techniques, he ignored the valuable contributions from Gropper's (1970) *text displays*, Holliday's (1976) *verbal flow diagrams*, and Spangenberg's (1971) *pictorial and verbal display diagrams*. 
Thanks to television programming, many individuals now have a heightened awareness of a kind of (memory) translation process. They happily translate what is experienced while watching TV. No wonder they have difficulty with the boring nature of most traditional learning materials (see Ortony's (1979) notions of boredom/tension).

According to Bisplinghoff (1993:448):

"in the current digital age of instant information, consumers encode and decode computer languages and symbols of electronic communication"

She explained that people become aware of the translation process necessary to access this new form of expression. Acquiring this translation process, can establish an increased awareness of the process of selection and interpretation involved in coding the particular messages.

2.1.2 (b) (vi) Nature of internal representation

The final role of cognitive strategies discussed here, relates to how they regulate our thinking processes. In fact, Kosslyn (1976) drew on a computer related metaphor to explain the human information processor. He proposed that images, once formed, are an unambiguous form of internal representation. Consequently, they were processed differently from other forms of representation. Once images were constructed, they took on the status of a representational medium, with special properties and characteristics of their own (Kosslyn, 1976). As a result, individuals may be unable to see the smaller properties of the image.

However, drawing on Riding's cognitive style construct, it is expected that some individuals will be unable to pick out the programming concepts from the metaphors (textual and/or graphical) implemented for this research.

If the image has been originally consulted by the individual for a particular property (Kosslyn, 1976); other associated properties are evaluated more quickly, when imagery is not used (Riding & Cheema, 1991).

This is not surprising because it is a direct (or 1:1) internal:external notational (Goodman, 1968) transfer.
Furthermore, Poltrock & Brown (1984) suggested, that information can be stored in, and extracted from, a visual image without the experience of seeing the image, even by individuals who claim to be unable to form a visual image.

2.1.2 (c) Verbal information

Acquiring the declarative knowledge required for writing new computer programs will involve learning the programming terms and basic rules. For instance: initialisation and data-types. This kind of information is described in many places as the most basic type of fact (or rote) learning. It can be thought of as pure verbalization, without any necessity for comprehension of the wider context. An individual can memorise it, or figuratively look it up, as single units or organized information (Martin & Briggs, 1986).

*To facilitate verbal information, verbal expositional strategies were employed as described by Rothkopf (1976) and Merrill, Li & Jones (1990). (See Figure:3.9 in Chapter Three: Literature Review, for an example of a verbal exposition strategy, implemented as an instructional strategy for this research).*

2.1.2 (d) Motor skill

It is not just the notion of movement per se that defines motor skills. An individual can say they have acquired a motor skill, when they can perform certain movements in a total action that is smooth, regular and precisely timed (Gagne, 1985). Other examples include the effective and efficient use of computer-input devices. For instance, operating a computer-keyboard and mouse as pointing devices. These motor skills involve highly developed eye-hand coordination.

2.1.2 (e) Attitudinal skill

Our attitudes influence (or moderate) our actions (Gagne, 1985).

*It is assumed from anecdotal evidence during this research, that learners have preconceived notions relating to their ability to perform the logical (mathematical) operations, involved in writing computer programs. The measurement techniques used to quantify cognitive performance will highlight the relationship between cognitive performance and test-item difficulty.*
Sonnier (1989) explained the importance of instructional strategies, which focus on how people feel about their learning experiences (affective education). As a result, the way people feel about a particular learning experience should be positive, if there is to be any lasting effect on the memory processing. Nevertheless, he noted that a negative experience (memory of the learning) does not have a lasting influence on our ability to recall learning. Unfortunately, this work is descriptive only. There were no suggestions on how to operationalize variables for research.

The discussion on the internal-conditions is now complete. The next section will concentrate on the external-conditions-of-the-learner. It is exclusively to these external-conditions-of-the-learner that most people refer, when describing instructional material per se.

2.2 External Conditions

To facilitate the learning process, the (external) conditions-of-the-learner have the capability to unlock our prior domain knowledge, or previous intellectual skills. In the case of mature age learners, who now face an increasing need to undergo retraining later in life, this is an immensely rich knowledge base.

This dissertation uses the term notational transfer to refer to this phenomenon that calls on the individual's ability to translate the external representations of the instructional strategy, to a form of internal representation (Figure: 4.5).

Over the years, there have been various calls for more research into adult learning (Ausburn & Ausburn, 1978; Joseph, 1987; Laurillard, 1993). A number of researchers have identified the need for further work to improve the external-conditions of the learner.

For instance:

1) perceptual representation (Palmer, 1977)
2) supplantation techniques (Ausburn & Ausburn, 1978)

This dissertation goes one step further, by investigating the interaction of external-conditions (specific instructional strategies enhanced with specific visual metaphors), and their possible interaction with the Riding & Rayner (1998) cognitive style construct (internal-conditions), for adult learners.
Pictures are used to help children read (Levin, 1981-a; Levie & Lentz, 1982). Surely, it can also be said that pictures also continue to help the adult population, especially when confronting new learning experiences.

This is especially apparent for adults, when learning new technological skills, as they may be placed in an unfamiliar environment (or a seemingly hostile context of external-conditions).

Levin (1981-a:203) was describing the notational transfer process, when using the term pictures to include:

"ones that are both visual illustrations that physically accompany a prose passage and analogous visual images that take shape only inside a learner's head."

For that reason, he believed this framework assumes that pictures in prose can serve multiple functions. For instance: in a functional analysis of visual-illustrations vs. visual-imagery, by presenting graphs, the basic message conveyed by that type of figure is twofold (Levin, 1981-a:217):

"First, the major impact of pictures on prose-learning facilitation is derived from their transformation function rather than from their representation function. Second, much larger facilitation differences between visual illustrations and
visual imagery are associated with the representation function than with the transformation function"

Consequently, the author believes that in this notational transfer process, novice learners are transferring the external-representation (what they see) into their internal-representations (how they think about it) (Figure:4.5).

In relation to the prose-learning findings, Levin (1981-a) proposed that pictures act as mnemonic transformations. This is apparent with prose that does not leap out easily, where the strain on one's comprehension and memory facilities can be considerably increased.

However, the concept of notational transfer is not new. In the past, it has been described as associative-learning. Similarly, facilitation produced by providing illustrations per se, is not nearly as great, as that produced by creating a meaningful associative link (Schank, 1975) between the paired items (Levin,1981-a). Such linkages invariably involve elaborations (Rohwer,1973), or transformations of the nominal stimuli, to render them more memorable.

Therefore, this research extends this phenomenon, calling it the internal/external exchange process, (described in the next sub-section 2.3).

Can visual metaphors, used as an internal/external exchange process, have the same effect (for some novice learners) in a computer-programming environment?

This dissertation seeks to explain how Riding & Cheema's (1991) cognitive style construct, interacts with particular procedural (abstract programming) knowledge tasks.

Given that individuals vary on the strength of their cognitive style, it is hypothesized:

that there will be some type of interactive effect of the visual metaphor
If so, can the explanation be found using *between-item* and *within-item* elaboration?

Furthermore:

<table>
<thead>
<tr>
<th>Is there a relationship between this phenomenon and <em>cognitive learning style construct</em> in the acquisition of abstract programming concepts?</th>
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</table>

The more detail present in an *image*, the more features must have been activated to produce it (Kosslyn, 1975), and the more extensive the resultant memory would be (see Kosslyn, in Ritchey & Beal, 1980). Refer to Chapter Three: Literature Review, topic 2.3.2 Visual representation, for an explanation of *within-item* and *between-item* elaborations.

However, there are a number of other problems associated with the *external-conditions* and have been under investigation. Novice learners need to be taught how to employ most *cognitive instruction strategies* (Reigeluth, 1983-b). In addition, while *graphical interfaces* present a huge range of colour-coded *instructional events*, nothing is known about the interactive effects of the *cognitive style construct*. Yet Levin (1981-b) argued that mnemonics are adaptable to student differences. Moreover, Dwyer & Moore (1991) suggested that significant differences in achievement, can be found between *field-dependent* and *field-independent* learners on a drawing test, although insignificant differences were found between *field-dependent* and *field-independent* learners, who had received colour coded treatments.

Researchers questioned the issue of semantic decisions, regarding *verbal* material being made in a *non-verbal memory system* (Rosinski et al., 1977). This uncertainty was supported by Riding & Cheema's (1991) research on the *cognitive style construct* (*mode of processing information/the representation of information during thinking*). Research should attempt to control the familiarity of the content to learners (Winn, 1981). He noted that his participants were already familiar with the insects chosen for his study.

Measuring learners' reactions to *visual material* requires special conditions. Thompson (1990) did not agree with a number of the self-reporting instruments used by researchers, while investigating the *visualization process*. Specifically, the *Verbalizer Visualizer Questionnaire* (VVQ) (Richardson, 1977) test referred to in many places in the literature. Poltrock & Brown (1984) commented on the VVQ preference test. However, they suggested that the test was appropriate. Nevertheless, Thompson (1990) believed it was not appropriate to simply ask, whether the individual tends to use *imagery*. O'Halloran & Gauvin (1994) noted some comments made by their participants, during and after their treatment sessions. They had
accounts from *imaginaries*-participants, reporting each time, that imagery in the *visual* mode was clear and vivid while imagery in the *auditory* mode was generally clear, and *kinaesthetic imagery* was mostly vivid and clear. This work involved ten trials of a *motor task*, using *visual*, *auditory* and *kinaesthetic instructional modes*, without any guidance by the tester. O'Halloran & Gauvin (1994) reported that all the *imaginaries* participants comprehended the instructions well, and were able to carry through on their own. Consequently, two thirds of their *verbal*-participants (9-out of 12-participants), reported their need to *talk* themselves through the *imagery*. This indicated they were using their preferred *verbal mode of thinking* to accomplish a more *visually oriented task*.

The author believes the O'Halloran & Gauvin (1994) research is an example of research, which lacks the benefit of the Riding & Cheema (1991) *cognitive style construct*. Of course, the *Verbalizers* responded accordingly, because they needed to externalise the subject matter in order to develop their *notational transfer ability*.

However, the Riding & Cheema (1991) *cognitive style construct* is only one way to describe the *conditions-of-the-learner*. The literature shows that researchers have been adding their own interpretation to this phenomenon over the years. Pettersson (1993-c) explained, for example, that humans receive and process information from their sensory systems in various ways. There are four preferences, humans may choose to use, when processing information:

1) visual
2) auditory
3) kinaesthetic
4) tactile

He presented a model to represent the perception of linguistic and iconic symbols.

Topics now planned for discussion include:

- **prerequisite learning**: to identify relevant prior knowledge
- **learning hierarchy**: to isolate entry level skills
- **instructional sequencing and events**: to implement the learning modules
- **learner characteristics and media**: to synchronise the internal/external exchange process
2.2.1 Prerequisite learning

At times, the *external-conditions* may make or break a learning strategy. For instance, computer-network manuals expect the reader to be computer literate. Consequently, it is essential that an individual possess the subordinate skills (which are assumed by designers to have been gained previously) to facilitate their learning process.

The participants in this study were not expected to possess any computer-programming skills.

Instructional designers are taught to conduct comprehensive *task analyses* (Zemke & Kramlinger, 1982; Mager, 1988; Dick & Carey, 1990). This systematic design process, assists with the development of effective learning materials. Be that as it may, unless this technique is properly understood, the research may be unproductive.

2.2.2 Learning hierarchy

Effective education calls for attention to both subject-matter knowledge and to general skills (Simon, 1978). *Learning hierarchies* properly designed and implemented are useful instructional design tools. A *learning hierarchy* gives rise to a *task listing*, which groups (clumps) related tasks in separate *learning modules* (McKay, 1999c). The power of this process is to allow the sequencing of *learning modules*, to suit the skill level of individual learners. Tasks identified in *learning hierarchies*, represent *intellectual skills* only (Aronson & Briggs, in Reigeluth, 1983-b). The targeted task can therefore be placed at the top of each module, with subordinate tasks arranged below. Consequently, these modules can then be arranged to show the relationships between each set of tasks. This is one way a designer can determine the opportunities for developing essential prerequisite knowledge.

However, lecturers design their instruction from their *perceived conceptual structure* which is stable and well defined (Laurillard, 1993). Consequently, the *learning modules* are often abstracted from the context in which the topic-to-be-learned exists. The result of this segregated learning experience is likely to be a lack of ability to transfer knowledge across different settings (Laurillard, 1993). Without these *integration skills*, novice learners have a problem in relating theory to practice. In other words, their knowledge is not context-related.

A combination of ethnographic and Vygotskian ideologies, gave rise to the notion that learning must be situated (Young, 1993). Therefore, *situated learning* produces knowledge through context-related activity (Laurillard, 1993). *Situated or conceptual knowledge* was defined as being similar to a set of tools (Laurillard, 1993).
2.2.3 Instructional sequencing issues

There were many apparent inconsistencies in the literature concerning *sequencing of instruction* (Mayer, 1977). Because of this, he suggested those *instructional strategies* that provide the necessary *internal conditions*, conducive to an enhanced learning experience, should comprise:

1. superordinate advance organizers
2. titles
3. heading
4. topic sentences
5. logical ordering
6. meaningful organization

The *instructional format* used for this research follows this framework.

2.2.4 Instructional events

*Programming metaphors* were an *instructional strategy* adopted for this dissertation. To operationalize this variable, they were expressed in two different ways: *text-only* and *text-plus-graphics* formats. For a description of these variables see Chapter Two: Literature Review, section 2. Instructional Format.

It was assumed that *verbal* deficient novice learners would benefit from the *external-conditions* (*instructional format*), that were designed as a type of *compensatory-supplantation strategy* (Ausburn & Ausburn, 1978).

The relationship between *verbal ability* and *performance on visual tasks* requires further explanation (Winn, 1982-a). Even so, he claimed that his current study was of value to science educators in two ways. Firstly, because the *picture-word diagrams* were useful for teaching *identification*, and that *block-word diagrams* facilitated the learning of *classification schemes*; secondly, because the effectiveness of the pictorial and organizational aspects of diagrams, appears to be related to the learner's *verbal ability*. Further research is needed to test this claim.
Levin (1981-a) also described a type of internal/external exchange process (discussed in the next sub-section 2.3), when he stated it is necessary to construct pictures that transform information, that are only weakly connected into more memorable representations. Therefore, the result of this weak connection, would be to facilitate the internal/external exchange process to occur, while the individual recalled a relevant experience, or event, from their sensori-motor database (Lindsay & Norman, 1977).

2.2.5 Learner characteristics and media

Most of the literature is written around the external-conditions-of-the-learner theme. This may be due in part, to the fact that for some researchers, this aspect is comparatively easier to investigate than tackling the complexities of the full internal/external exchange process.

English-speakers will tend to read diagrams, in the same fashion they read language; left to right, and top to bottom (Winn, 1982-b). He raised the issue of crystallised intelligence and fluid ability, while explaining the difficulties for researchers surrounding spatial ability testing. He argued, that spatial ability testing may not predict a learner's success with a spatial treatment. This test was fraught with evidence of conflicting research results, sufficient, in fact, to justify the claim that certain tests used to predict outcomes in ATI studies, using a visual treatment, often tap different skills required by learners to complete a task.

In relation to gender differences in imagery ability, Coltheart, Hull & Slater (1975) suggested females perform better than males on:

1) verbal tasks
2) verbal fluency
3) articulation
4) spelling

Conversely, they argued that males are superior on:

1) visuo-spatial tasks
2) maze learning
3) form-board tasks

Although they pointed that out there were exceptions to this premise. Furthermore, they argued, that it may prove efficient to teach girls to read by phonological method (phonics), and boys to read by visual method (whole-words).
The propensity to think verbally may have deep-seated ramifications in the classroom. Visualizers are under represented among the gifted mathematics pupils. Teachers seem to favour Verbalizers as the high achieving stars of the classroom (Thompson, 1990). He suggested that previous research into visual imagery has been from distinct, and at times, quite separate disciplines. Each field of concern was reflected in the majority of the references quoted by authors. Consequently, the opportunity to unify their research, through a unified topic such as visual imagery, was therefore lost. Individuals may be more visual in particular occupations than in others (Thompson, 1990). For instance, biologists and experimental physicists are more visual in their thinking, while theoretical physicists, psychologists and anthropologists are more verbal.

To reduce the likelihood of homogeneity in the research population for this research, the final experiment was set in a generic learning environment, where a large cross section of participants was possible.

The author believes that the acquisition of complex programming concepts requires dual-coding skills. This is because, the capabilities needed for program design and writing algorithms necessitate quite different cognitive skills.

In fact, Herbison-Evans (1988) in his notion of four-dimensional thinking explained that the mindset of people in various disciplines may be characterised by the dominant dimensionality of thought needed to perform their work. As such, he introduced the dimension of time as a variable. For instance, computer-programmers typically need to think in one-dimensional character strings. Engineers and architects are inclined to reduce everything to two-dimensional drawings. Sculptors and surgeons need to think in three-dimensions. Four-dimensions were the domains of (amongst others), physicists and dancers.

Furthermore, in a computerized learning environment, the author believes this is the crux of the problem instructional designers face when considering the external conditions-of-the-learner. Nevertheless, these (generic) instructional strategies must reach a very broad range of individuals.
3. Interactive Effect of Internal/External Conditions-of-the-Learner

The mental skills used by learners require study as well as the learning outcomes (Salomon, 1979). There have been a small number of researchers looking at the interactivity issues of internal/external conditions-of-the-learner. For instance, Clark (1994) proposed that only certain media attributes are more efficient for certain learners. Therefore, research which follows this tack, he says, will allow the mental set theorists to shift from focussing on media attributes as causal in learning, to media attributes as causal in the cost effectiveness of learning instead.

Notation transfer ability (Figure:4.5) as used in this research, describes the strength of the internal/external exchange process that occurs within a learner during a learning experience.

In fact, Sternberg (1977) almost described the interaction of internal- and external-conditions-of-the-learner as an assimilative set, which should be available and active during learning. He described the concept assimilation-to-schema as the:

1) reception of the to-be-learned material
2) availability of a cognitive structure
3) activation of the structure during learning

It is through the interaction of communication with technology that humans now have an even greater capacity to store and retrieve vast quantities of information (Baddeley, 1982; 1990). As a consequence, he considered the progression of our ability to communicate through writing, film making, and indeed television, to be a physical extension of the human memory.

Finally, it is necessary to focus on the issues relating to the internal/external exchange process, including:

- influencing the internal/external exchange process
- internal and external orientations of the conditions-of-the-learner

3.1 Influencing the internal/external exchange process

There was an assumption that this dissertation would find an interactive effect between instructional strategy and cognitive style, as this is the common view from the literature.
Moreover, the isolation and characterisation of such an effect would have great value in planning future research.

We learn a language at the very basic level of word meaning (Wittgenstein, 1963; Rosch & Mervis, 1975), and thereby named objects because they are pointed out to us when we were young. Consequently, the meaning associated with intentions are learnt by observing body movements. Observing facial expressions and tone of voice thus enable us to gradually express our own ideas to others.

There is evidence from the literature to infer that we have a natural propensity to profit from our visual representational abilities. Nonetheless, the account of our visual experience will differ, according to how much we know about it. The only thing that is natural to us is the ability to represent what we see three-dimensionally (Wittgenstein, 1963), who proposed that we need special training for two-dimensional representation. This applies to words as well as drawings.

Thinking means an internal looking process (Figure: 4.6). In other words, thoughts are in fact visual representations that arise when we think (Pettersson, 1993-a). Wittgenstein (1963), while explaining the meaning of a concept, referred constantly to our visual experience when describing things, suggesting that we look instead of think about something.

Furthermore, we see a complicated network of similarities of detail, crisscrossing and overlapping each other. Sternberg (1977) referred to this phenomenon as the overlapping of conceptual, local sub-spaces. Wittgenstein (1963) categorized these similarities as family resemblances, within and between members of a family (not to be confused with the Rosch & Mervis (1975) taxonomy of family resemblances, or Merrill et al.’s (1992) concept taxonomy).

There are two uses of the word see, according to Wittgenstein (1963): seeing a direct copy, and seeing a likeness between two objects. As we interpret things, we see by imagining a particular visual experience of the thing. When asked what we see when observing an object, our recollection will include contextual images before we can make a report of what we see. Therefore, the report in this sense, and the exclamation, expresses the visual experience, as well as the perception (the context). He argued that the exclamation was related to the experience we have when perceiving the object.
As a result, perception involves our senses immediately before our complex cognitive processes. Cognition involves processes that relate the new material to the relevant aspects of our existing cognitive structure. For that reason, we can reconcile new meanings with our established knowledge, using a familiar style of language (Ausubel, 1968-a). For understanding to occur, Pask's (1972) Conversation Theory demonstrated this process was possible using technology as a type of internal/external exchange transfer agent, whereby agreement must take place between the private (internal) and the public (agreed external) representation.

It was also thought by Ausubel (1968-a) that perception precedes cognition, in the meaningful learning of new propositions. For instance, in order to understand a sentence an individual must be able to:

1) perceive the potential, and propositional meanings
2) incorporate this perceived potential meaning within their existing cognitive structure
Evidence from research showed that individuals who tend towards the *Wholist cognitive style* may have great difficulty with this activity. They may be unable to *dismember* enough detail (Figure:4.6).

*Therefore, the author believes individuals who possess this cognitive characteristic must have access to instructional strategies like Ausburn’s compensatory/conciliatory supplantation techniques* (see Chapter Two: Conceptual Framework, section 1. Instructional Science Paradigm).

Ausubel (1968-b) maintained the first step implies both adequate knowledge of basic functions and syntax (rules), while the second step implies relating the perceived proposition to relevant anchoring ideas in cognitive structure. However, this *internal/external exchange process* alters as an individual becomes familiar with new material (Dreyfus & Dreyfus, 1986). Although acquisition of meanings was a cognitive process, Ausubel (1968-b) argued that it was proper to refer to the cognitive content evoked by an individual's existing meaningful proposition, as a product of perception (rather than of learning). However, perceptual representation involves numerous levels of representation in the form of hierarchical networks (Palmer, 1977).

*It can be said there is a level of tension between a machine-generated representation, and a mind-generated representation.*

*There is no evidence that research is able to describe this phenomenon correctly. Much needs to be done to identify the internal/external exchange process, which enables the notational transfer* (like the external one-to-one representation of concepts found in street maps) *to an acceptable form of aggregated internal representation, which is non-notational.*

However, natural superordinate semantics have prototype structures (which exhibit an internal/external notational-like relationship) to which humans reliably categorize, according to their own idea or image of the meaning of the category name (Rosch & Mervis, 1975). Furthermore, referents of a word do not necessarily need to have common elements in order for that word to be understood and used in everyday language (Rosch & Mervis, 1975).
However, the mind can play tricks. Learners could acquire complete ideas from exposure to partial ideas. The acquisition of ideas is so natural and compelling that the learners would actually think they had heard sentences expressing the complete ideas during acquisition, when in fact they had not (Bransford & Franks, 1971). There are many examples of the illusion of certain types of visual stimulus material (Pettersson, 1993-c:107):

"Visualizing is the ability to form mental pictures"

He argued, that these mental pictures do not necessarily develop from an external source. It is quite possible for individuals to derive an image by thinking, giving rise to an inner image. The perception of these inner images, may encompass a wide spectrum of representation, from the purely abstract, to highly realistic sensations. The internal/exchange process can occur in two ways. According to Pettersson (1993-c) they were:

1) primary
2) secondary visualization processes

Primary-visual-imagery is the result of external stimuli, with the perception of vision being created in the brain and stored as imagery in memory (Figure:4.6). While secondary-visual-imagery is then generated by internal stimuli. However, there are times when external stimuli can initiate secondary-visual-imagery, including memories, thoughts and dreams.

Therefore, the visual metaphors adopted for this dissertation, were innovative primary-visual-imagery tools to facilitate perception, and thereby promote action in the form of cognitive performance.

Language devices function to adapt language users to the world (Dent-Read & Szokolszky, 1993). Consequently, metaphor in language is no exception. They suggested however, that metaphor needs a definition more specific than a language device. Therefore, they defined metaphor as (Dent-Read & Szokolszky, 1993:230):

"a species of perceptually guided adaptive actions that may or may not be expressed verbally"
3.2 Internal orientation

The visual metaphors used in this dissertation will require the participants to adopt an *internal/external exchange process*. The strength of this process will be measured and discussed in Chapter Seven: Meta-Knowledge Acquisition Process.

Not all of us see in the same manner; there are non-seeing sighted individuals! (Lowenfeld,1945; Howell,1972). There are two distinct (perceptual) types of people, regardless of whether they are normally-sighted or blind (Lowenfeld,1945):

1) haptic
2) visual

For instance: an individual analyses an object into detailed or partial impressions. These segmented details were then rebuilt into a new synthesis of the original whole. Subsequently, he was able to show that extreme *haptic*-*types* have normal sight, and used their eyes only when compelled. Consequently, these individuals react as would a blind person who was entirely dependent upon touch and kinesthesis. Furthermore, according to Lowenfeld, this perceptual-type is not rare.

Therefore, some individuals may have a highly developed *notational transfer* ability.

Highly creative people often report a preference for using *imagery* in their creative endeavours (Isaksen et al.,1991-1992). In several theories of *symbolic processing*, the relevance of *imagery* was often linked to the more abstract aspect of problem solving, where the task at hand was novel, unstructured or highly complex. However, according to Isaksen et al. (1991-1992), this approach may have an important limitation due to not making a distinction between conscious representations that are *verbal* and *imaginal* in nature.

However, semantic processing is a memory function individuals are very familiar with in everyday life (Bransford & Franks,1971).
3.3 External orientation

It has been stated earlier, that this research draws on the Reigeluth Elaboration Theory of instructional strategy, because it forces learners into deeper processing. In the main this work directly associates the external orientation of the instructional strategy with the internal orientation of an individual in a generic fashion.

However, there was no evidence in the literature, which accounts for measuring an individual's attitude to technological interaction in the learning environment (Laurillard,1993), although a phenomenon known as computerphobia has been identified by Tharp (1987). The amount of adult learning research into this matter is, therefore, limited.

Due to the fear of technological learning (or the experience of an unfamiliar cognitive state), the retraining process can be very painful for some individuals. This is a complex issue, which many adult novice learners face. This may explain what happens when individuals appear to freeze-up in the computerized learning environment (McKay,1999c).

Instructional strategies, which require a notational (external) transfer to a notational (internal) representation, are dull.

Paivio (1971) advanced notions that the learning of how to order a set of pictures activated a verbal labelling system. This system seems to be specialized for concatenating discrete, sequential events. Therefore, high label similarity disrupts serial reconstruction equally for both pictures and words, suggesting that label codes were reintegrated, and were being used equally for each type of stimulus (Nelson, Reed & McEvoy,1977). When pictures serve as a paired-associate stimuli (for a straight one-to-one notational internal/external exchange transfer), high levels of label similarity have no effect (Nelson & Brooks,1973). Stimulus recognition is required and is relevant to a computerized learning environment.

Although they were mainly working with adolescents, Thompson & Riding (1990) raised some obvious questions that include measuring facets of student control over their learning environment. Adults expect to have a certain amount of control over their learning environment, according to the Keller Motivational Design of Instruction model (Keller, in Reigeluth,1983-b).

The earlier research on cognitive styles, which began four decades ago to explain the fundamental qualities of field-dependence/independence, was also investigating the internal/external exchange transfer process.
Witkin's (1950) famous experiments explored how individuals locate the upright (external) space, using a manipulable visual framework, while at the same time, separating the visual and bodily standards of the individual's perception of uprightness (Witkin, Moore, Goodenough, & Cox, 1977).

Lowenfeld (1945) demonstrated with a series of aptitude tests, that there were two distinct creative types, based on two unlike reactions toward the world of experience. It was shown that the inability to notice visual objects was not always inhibitory of creative activities. The very fact of not paying attention to visual impressions, may be due to the haptic aptitude. One factor in visual observation noticed by Lowenfeld (1945) was the ability to see the whole object without awareness of detail. This observation maps directly with Riding's notions of mode of processing information.

Moreover, Bransford & Franks (1971) raised the need to determine the effects of different acquisition instructions. For instance, individuals on the Wholist extreme of Riding's mode of processing information continuum have difficulty disembedding the facts (Figure: 4.6). Another important and well-recognized experiment was the embedded-figures test, which involved an individual being given an item to inspect visually (Thurstone, 1938; Witkin, Oltman, Raskin & Karp, 1971). It was a simple geometric design, contained within a complex and organized (visual) field. Some individuals quickly found the embedded item, while others were not able to identify the embedded item within the specified time of the test. This observation, maps directly with the Analytic characteristic, of Riding's mode of processing information continuum.

Summary

The purpose of this chapter, was to describe the knowledge acquisition context, in which to locate the research variables in ways that are observable and measurable (Ausburn & Hedberg, 1981). Instructional conditions were shown to involve three major components: methods, conditions, and outcomes. They articulate the strategic knowledge context planned for this research programme. As a result, the most important set of variables are the conditions, which on examination are very complex, due to the need to separate the ones which can be manipulated (instructional format), from the ones which cannot (learner characteristics) (Reigeluth, 1983-b).

An instructional model was devised to locate each component, as separate modules, in a theoretical structure, whereby interactivity can be expressed within and between each module (Figure: 4.2). The conditions-of-the-learner is the primary variable, for describing
the strategic knowledge context for this research. The major differences between the internal- and external-conditions-of-the-learner were defined to differentiate the (internal-) states within a learner that are involved with the act of learning, and the (external-) events occurring outside of the learner, that support an individuals’ internal learning processes. However, learning modules are often dealt with in an abstracted manner (Laurillard, 1993), distanced from the learning content topics. Consequently, the acquisition of knowledge is generic, and often not context-related.

The external-conditions warrant thorough examination. They appear to either provide the capacity for unlocking an individual's prior domain knowledge, or may facilitate a hostile instructional environment, where learning becomes more difficult. The term notational transfer was introduced to describe the translation process for converting external representations of the instructional material into an internal form to facilitate learning (Figure:4.5). In the past, associative-learning was used to describe this process. However, in the current context, the term internal/external exchange process is used as a possible speculative mechanism, to incorporate the phenomenon of combining verbal/visual instructional formats.

Interest in the relationship between learner characteristics and media is sparse. A great deal more work is needed before we can correctly describe the relationship between verbal ability, and performance on instructional outcomes involving visual media. This research aims to investigate the interactivity issues, which envelop the internal/external dimensions of the conditions-of-the learner. In so doing, Pask's (1984) conversation theory, and the concept of prototype structures (Rosch, 1975-a), are revitalised in the components of an individual's notational transfer ability. However, it is the next chapter, which draws together the richness of previous research to devise the means to operationalize these complex variables.
The previous chapters have exposed diverse perspectives of educational experts on knowledge acquisition and related cognitive issues. While chapter four in particular, provided expanded definitions of key-terms used for this thesis, the purpose of this chapter is to unify the diversified complement of research elements into a fusion of strategic knowledge (Lukose, 1992).

However to maintain taxonomic validity in such a complex domain, it is necessary to distinguish the research methodology from the knowledge-mediated experimental design, to fully exploit the opportunity to investigate programming knowledge acquisition.

In doing so, the meaning and relationships of variables, and the number of factors, which need to be taken into account, are correctly identified.

Research has shown that teaching new computing concepts to visual thinkers requires appropriate instructional strategies (Smith, 1998). Therefore, the major factors, which influence the learning process in a computer-mediated environment, are postulated to be:

- the type of concept-to-be-learned, and the expected instructional outcomes
- an individual's existing knowledge of the concept's domain
- an individual's information processing abilities, and the cognitive strategy they employ
The influence of these factors commences when a novice approaches a new learning environment, which may or may not be sympathetic to their needs (Laurillard, 1993).

In education, we need to be more willing to develop strategies to suit the needs of individual learners. At an early stage, success can be assessed by a learner's ability to discriminate between new and existing concepts. Providing them with suitable analogies between concepts can sometimes help. The instructional strategies which are used should be those, which best suit the ways that learners think and learn. Although both text-based and pictorial-based material can be used in each case, the instructional material for adult-learners should be biased towards the cognitive style construct of each learner. Reigeluth (1983-b) used the term the conditions-of-the-learner, to describe the effects of combining the internal states and external events on learning.

This research draws on the conditions-of-the-learner to provide the computer-mediated context (Figure:5.1) for the strategic knowledge level of goal directed learning (Lukose, 1992).

Understanding this context (Hoffman, 1998), will help researchers reconstruct the way that individuals deal with structure, and subsequently remember their prior experiences. According to popular belief, imagers (pictorial-thinkers) seem to experience difficulty with learning material, which is predominantly text-based; just as Verbalizers may have a similar difficulty with pictorial or graphical material. Visual-thinkers may have to translate text into a graphical form, before they can absorb the information they receive and order it in their own ways.

It is common opinion amongst researchers, that this process may seem unsympathetic, with outcomes that will be tiring and even stressful (Douglas & Riding, 1993). Verbal-thinking learners may be similarly stressed, by trying to learn from pictorial-based material. They may miss out on the overall picture of the learning material, whereas their pictorial-thinking counterparts, who take a broader sweep of the same material, may ignore the fine detail involved (Laeng, Peters & McCabe, 1998).

However, for a computer-mediated environment, it is the level of interference from the complex nature of the learning task that needs investigating (Yost, Varecka & Marefat, 1997).
For instance, in previous studies, which involved an individual's capacity for spatial relations and analogical reasoning (Hummel & Holyoak, 1997; Dierbach & Chester, 1997; Hosenfeld, Van de Maas & Van den Boom, 1997), this important variable appears not to have been investigated.

As a consequence, the process of merging previous research contributions has produced three knowledge levels that articulate the holistic basis for this research.

The first level of discourse relates to the fusion of strategic knowledge required to provide leverage for conducting the experiments. The second level deals with the mechanisms designed to elicit the acquisition of enabling cognitive strategies an individual requires to achieve the instructional outcomes. While the third level describes the final experiment and the inherent environmental elements, which impact, on the results.

Therefore, the following sections discuss these three knowledge levels as:

- **Research process**
- **Acquisition of programming knowledge**
- **Innate environmental factors**
1. Research Process

Testing for the interactive effects of the internal/external exchange process, which occurs during the learning of computer programming, is complex. Many variables cause interplay between the internal/external conditions-of-the-learner. Consequently, a staged research programme was implemented to reduce the number of unknown confounding variables and flush out some of the more noticeable interacting variables. The research programme began with a series of exploratory studies (McKay, 1999a; McKay, 1999b). Once these pilot study results were known, the final experiment was run (see this chapter, section 3. Innate Environmental Factors, and Appendix Item: McKay & Garner, 1999).

The purpose for setting the experiments within the field of computer programming was:

- to identify the specific knowledge requirements for dealing with logic operations
- to identify the cognitive strategies a novice-programmer must employ to become proficient
- to propose a meta-knowledge processing model (see Figure: 1.1, in Chapter One: Introduction).

A novice-programmer needs to deal with the vast amount of verbal information relating to the abstract nature of the procedural programming knowledge. Accordingly, the richness of these abstract knowledge requirements, together with the diverse nature of the cognitive strategies that are needed to accomplish writing a program, gives rise to a comprehensive set of learning modules for each specific task required for each specific programming knowledge instructional outcome.

Therefore, the instructional outcomes were measured in terms of cognitive performance on a range of specific tasks designed to test for specific cognitive strategies, thereby identifying an internal/external exchange process, which is involved in this type of knowledge acquisition.

Testing the interactions of the internal/external conditions-of-the-learner with instructional strategies was implemented using instructional material involving textual and visual learning components.
There were two exploratory studies and a final experiment conducted for this dissertation. Overall, the experiments have spanned four-years, commencing with the first study in 1994 (McKay, 1999a), and ending with the final experiment in 1997. Each experiment consisted of four stages (Figure:5.2):

- cognitive style screening test
- pretest to determine prior domain knowledge
- instruction period
- post-test

Over time, the research programme evolved from the initial investigation of adding a visual representation strategy to an existing text-based instructional format (for writing a PASCAL program) to a comprehensive experiment, which tested for the interactive effects of instructional format (programming metaphors) and cognitive style construct (Wholist-Analytic/Verbal-Imager) (Riding & Cheema, 1991) on the acquisition of logic flow concepts.
For the full description of cognitive style, see sub-section 4.3 of Chapter Two: Conceptual Framework.

It was anticipated that this research would inform the design of an interactive online courseware shell that provides an opportunity to align cognitive style and instructional format.

The following sub-sections explain how the research process evolved, including:

- An overview
- Building the context
- Research objectives
- Strategic programming knowledge concepts
- Concept classification

1.1 Overview

The process of identifying the research variables began with the exploratory studies. The Verbal-Imagery dimension was used as an independent variable, to split the sample into verbal and visual treatment groups. A pretest was used to indicate participants' prior domain knowledge to enable measurement of improved cognitive performance on a post-test. Overall, four programming instructional booklets were created (see Volume: 3):

- the first booklet enhanced existing text-based instructional material (Bagley,1990) with a mnemonic strategy (pictures/graphics) which was used for the initial exploratory study (McKay,1999a)
- the next three booklets, represent the instructional programme designed to elicit specific cognitive performance benchmarks for programming knowledge, that were used for the second exploratory study and the final experiment (McKay,1999b). The first contained pre-instructional materials, while the remaining two-booklets were used as the experiments' treatment.

In the first exploratory study, the post-test score was the dependent variable with post instruction performance measured by subtracting the pretest scores from the post-test (McKay,1999a). While in the second and the final experiment, it was cognitive performance on instructional outcomes that was measured (McKay,1999b). Following is a short description of the first two studies.
1.1.1 First exploratory study (Pilot-1)

The aim of the first experiment was an attempt to:

investigate the interaction of cognitive style (Verbal-Imagery) and instructional material (enhanced with graphics) with the acquisition of abstract computer programming concepts.

It was hypothesized:

<table>
<thead>
<tr>
<th>that Verbalizers learn abstract concepts differently from Imagers, because they have received text-only instructional material. Likewise, Imagers learn how to apply abstract concepts in varied contexts differently from the Verbalizers, because they are able to transfer Images of abstract programming concepts into new computing contexts.</th>
</tr>
</thead>
</table>

Therefore, it was assumed that Verbalizers would learn new programming concepts better with a text-only instructional format than with the text-plus-graphics. Imagers however, would learn the same set of concepts more effectively with the text-plus-graphics format.

However, Pilot-1 suggested that the Verbalizers appeared to learn the targeted programming concepts better with the text-plus-graphics format (McKay,1999-a).

Conversely, Imagers were unable to translate the graphical representations into new contexts, and therefore performed better with textual description of the programming concepts.

1.1.2 Second exploratory study (Pilot-2)

The second experiment shifted the focus from the broad programming learning outcomes, with instructional material enhanced with graphical representations, to take a more selective approach, and explore the relationship of instructional format and cognitive style (McKay,1999b).

The aim of this experiment was to explore the following question:

**to what extent does matching instructional strategy with cognitive style enhance performance in a structured programming task?**
Based on the findings of Pilot-1, which were contrary to popular belief, that Verbalizers perform best when receiving textual information (Riding & Caine, 1993) and that individuals who prefer to think using pictures rather than words benefit more from mental imagery, than people who use words (O’Halloran & Gauvin, 1994), a number of hypotheses were proposed.

It was hypothesized in the second experiment:

that the Verbalizers learn abstract concepts differently from Imagers; they will benefit from the text-plus-graphical metaphor instructional strategy. Furthermore, Verbalizers learn how to apply abstract programming concepts in varied contexts differently from the Imagers. Likewise, Imagers will be unable to utilize the graphical metaphors to improve their acquisition of abstract programming concepts.

Verbalizers appear to be better at transferring their conceptualisation of the graphical representations into new computing contexts.

Therefore, it was proposed that Verbalizers would learn new programming concepts better with a text-plus-graphical metaphor format rather than the text-plus-textual metaphor material.

Conversely, it was proposed that Imagers would learn the same set of concepts more effectively with the text-plus-textual metaphor format.

1.2 Building the Context

An important element of courseware design is the attention given to the anticipated characteristics of the target learners (Dick & Carey, 1990). Therefore, to establish details relating to particular characteristics of the tertiary population (from which the sample would be drawn), a questionnaire was given out to first year students (Mager, 1988). This profile facilitated the design of instructional materials for the internal/external conditions-of-the-learner. The results of this questionnaire revealed details on:

1) their physical characteristics
2) formal training
3) anticipated attitudes
4) their sources of reinforcement
1.2.1 Physical characteristics

They will range in age from 18 to 48 years. The sample would be half female and male; some would be living at home with parents; most travel independently (by car); and there would be no apparent physical limitations (assistance to be provided if additional support is needed).

1.2.2 Formal training

There would be varied levels of computer literacy. Most will be undergraduate students with some post-graduate mature age participants; all will have experienced training type workshops/tutorials; some participants would be articulating from Technical and Further Education (TAFE); most will have completed VCE; English reading and writing skills are assumed to be well developed; the recent school leavers will have well developed computer literacy skills; mature age participants may require an additional introduction to DOS; some may possess limited/weak computer literacy skills; participants with applied science backgrounds may posses mixed levels of computer literacy. Within this group, there may be a higher tendency for *haptic* tendencies (Lowenfeld, 1945) and with lower *verbal* processing skills (tutors' tutorial observations). There may be several of them exhibiting the *dependent* cognitive style, with fewer *independents* (Moore & Bedient, 1986). While those students possessing a high computer literacy level may have lower than average reading/writing skills. They may not be able to concentrate for long-periods and may not realise that they know how to write an algorithm. Finally, some participants may be familiar with a 4GL (known as procedural languages, which automate the programming procedures, rather than have the programmer direct every part of the process).

1.2.3 Anticipated attitudes

A free training workshop for further business computing studies will be appealing. They should be eager to participate in an accelerated learning programme to achieve course level knowledge without the stress involved with a formal exam process. There will be a willingness to transfer learning to related learning domains. They may exhibit apprehensive tendencies towards their ability to perform logical processes. In relation to their interests, they will be highly varied. Some may have self taught computer literacy skills; few will be married; some will have family commitments; and some younger participants may socialise freely on campus during other studies.
1.2.4 Sources of reinforcement

Skills gained during the workshop can transfer to other computing packages. For instance, to object oriented programming knowledge, and database programming environments.

1.3 Research Objectives

The overarching question raised by this dissertation is:

**Does the interaction of instructional format and the cognitive style construct effect the acquisition of abstract programming concepts?**

There is no experimental evidence to validate these issues in the context of computer (knowledge)-mediated learning. Therefore, the final experiment will attempt to provide relevant evidence to test the following hypotheses:

The first hypothesis tests whether *instructional format* affects the acquisition of *abstract programming concepts* in terms of the Riding & Rayner (1998) *cognitive style construct*. For instance, do the *Analytic-Verbalizers* perform best when receiving *text-based* instructional material? Conversely, do the *Wholist-Imagers* perform best when receiving *pictorial-based* instructional material?

Therefore the first hypothesis formulated a general statement covering the overall purpose of the study:

\[ H^1 \text{ Instructional treatment will have an effect on the cognitive performance of one cognitive style group compared to another.} \]

In order to analyse the effects of *instructional treatment* and the *cognitive style construct*, it will be necessary to conduct separate comparisons of each independent variable. For instance, can it be shown that the effects of instructional format will be different for a particular group of individuals? In other words, can it be shown that the individuals who possess the same *cognitive style characteristics* (*Wholist-Verbalizer, Analytic-Verbalizer, Wholist-Imager*, and *Analytic-Imager*) perform any differently from their counterparts receiving the contrary instructional format (*text-plus-textual metaphors/text-plus-graphical metaphors*)?
The second hypothesis was:

\[ H_2 \text{ Cognitive performance will be affected by the type of instructional treatment they receive.} \]

Therefore, analysing the separation of the independent variables, the cognitive performance within each instructional treatment is necessary. For instance, can it be shown that different cognitive style groups (Wholist-Verbalizer, Analytic-Verbalizer, Wholist-Imager, or Analytic-Imager) perform differently when given the same instructional format?

The subsequent hypothesis was:

\[ H_3 \text{ Cognitive performance will be affected by the individual's cognitive style.} \]

To complete the analysis of the interactive effect of instructional treatment and cognitive style on the acquisition of abstract programming concepts, an investigation of the interaction of cognitive style and instructional format is necessary. For instance, can it be shown that Verbalizers receiving the text-plus-textual metaphors perform differently from Imagers receiving the text-plus-graphical metaphors?

Therefore the final hypothesis this dissertation investigated was:

\[ H_4 \text{ Cognitive performance will be affected by the interaction of cognitive style with the type of instructional treatment.} \]

1.4 Strategic Knowledge of Programming Concepts

There were three instructional modules identified in the learning hierarchy for writing new PASCAL programs (Figure:5.3). Describing the modules in terms of the anticipated instructional outcomes required to demonstrate strategic programming knowledge, they are:

- **the entry level skills:** basic computer literacy
- **problem solving:** redefining the problem to prepare an algorithm
- **knowledge of the programming language rules**
Each module identifies a sequence of tasks necessary to achieve the *instructional outcome*. As described earlier in Chapter Three (topic 1.1.1 Accessing knowledge), prior learning experiences can have an interactive effect when assimilating new information.

The process of acquiring the *procedural knowledge* required for computer programming, involves the *internal/external exchange process*. It was necessary to determine levels of previous familiarity with similar cognitive processes. Therefore, when the participants were tested, they were encouraged to answer in their common idiom. This was a deliberate attempt to identify levels of *prior knowledge* applicable to programming.

The next two topics explain how *prior domain knowledge* was determined in Pilot-1, followed by the lessons learnt from this, and from other relevant research.

1.4.1 Defining prior domain knowledge level (Pilot-1)

*Prior domain knowledge* was defined as the learner having previously developed prototypes of abstract concepts, specifically within a computer-programming context. The participants were classified as possessing *novice* or *experienced programming knowledge*, according to their *pretest score*. In the first exploratory study, *novice-programming knowledge* was selected as a *pretest score* of <28%. It was deduced from these figures, that these participants had no *prior knowledge of programming*. *Experienced programming knowledge* was reflected by a *pretest score* of =>28%. None of these *experienced programming*
participants had professional experience in computer programming. Like the Bagley (1990) study, their experience with programming, was limited to previous courses at secondary college, and/or exposure to other programming languages.

1.4.2 Benefit of hindsight (Pilot-2)

The instructional content was more focussed by narrowing the context (Figure:5.4). Therefore, the definition of the independent variable (instructional strategy) had become more complex (the additional programming metaphors). Given that these metaphors were to act as active cognitive processing agents, the importance of locating the participants' prior domain knowledge levels became more evident.

Although the participants were novice-programmers, the high performance levels on the pretest for the first exploratory study (Pilot-1) can be explained by the association learners can make between new information and prior knowledge, when using an elaborative interrogation strategy (Woloshyn, Wood & Willoughby,1994). They suggested that learners were able to make inferences and elaborations about new materials by answering why type questions. This means, that the simple or basic nature of the original Bagley (1990) pretest may have provided the equivalent of an elaborative interrogation strategy. This being the case, an alternative assessment methodology, to accurately measure the changes in cognitive skills performance, was chosen for the final experiment. The effects of prior domain knowledge (investigated by Bagley,1990), were further minimised by using the same structured format in both instructional booklets for both treatments.

1.5 Concept Classification

The way people use concepts is context dependent (Wilson & Tessmer,1990). In keeping with this view, a concept classification system was designed to integrate the textual information presented in the instructional booklet with the participants’ existing experiential knowledge.

Therefore the instructional outcomes in Bagley’s (1990) thesis were categorized into four programming concepts:

- Rule
- Concrete
- Abstract
- Process
For the full discussion on how concepts are defined for this dissertation, see Chapter Two: Conceptual Framework, section 2. Concept Learning.

To understand computing terms and processes, a novice-learner must rely on the strength of their internal/external exchange process ability to translate the newly presented terms into a meaningful context.

Rosch (1978) observed that, in the absence of a specified context during an experiment, participants would make a contextual assumption for that particular concept.

Therefore, in learning logic operations for programming, isolation from an involvement with the prior experiences of the (adult) novice-learner; (this lack of context) may account for the large numbers of individuals, who have trouble in developing this type of knowledge.
2. Acquisition of Programming Knowledge

The second level research objective is to locate the variables, which instigate the learning process. Because of the need to devise a reliable way to measure the interaction of delivery strategies and cognitive style, the *instructional treatment* was an important *independent variable*, as it directly relates to the *internal/external exchange process* by linking the major components of instruction; *method of delivery, instructional conditions*, and *instructional outcomes* (Reigeluth, 1983-b). As such, these variables can be taken up as distinctly different research treatments (Figure:5.5). Consequently, it was important to employ a learning domain, which could be broken into discrete modules for the purpose of measuring strength of *cognitive performance*.

The main *instructional outcome* was to devise an *instructional strategy* for acquiring the cognitive skills to develop programming algorithms, which use the *DOWHILE* and *REPEAT UNTIL* control structures.

The following sub-sections discuss how the experimental design evolved, including:

- Research parameters
- Mechanisms to elicit strategic programming knowledge
- Defining the learning content
- Motivational tools
- Validating the learning content
- Measurable instructional outcomes
- Instrumentation

2.1 Research Parameters

There were no computer-related experiments that were suitable to convert into an empirical study for investigating the *external conditions-of-the-learner*. Therefore work proceeded on converting a study conducted by Dr Carole Bagley, in 1990. Her study involved an investigation of *structured* versus *discovery instructional formats* for improving the learning of programming concepts by *novice and experienced adult learners*. The strong instructional design framework of this research is a fine example of how to clearly define the parameters of each research variable (Merrill, 1994).
Consequently, the *instructional treatment* used in the first exploratory study consisted of the Bagley (1990) self-paced *Structured Instructional Format Booklet*. Figure:5.5 presents some of the key research parameters used in this design, including:

- **the method**

  *learning content*

  *instructional conditions*

  *presentation mode*

  *specific learner characteristics*

- **the measurable learning outcomes**

  *instructional method*

  *cognitive style construct*

### 2.2 Mechanisms to Elicit Strategic Programming Knowledge

After running the first exploratory study, it was felt that limiting the learning content to *programming logic patterns* would provide a more robust research design. Therefore, in order to conduct an empirical experiment, a new self-paced instructional booklet was designed to isolate the *internal/external conditions-of-the-learner* and to take advantage of the *notational transfer* that occurs when assimilating new information with previously learned *cognitive strategies* (See Volume: 3).
Acquisition of Programming Knowledge

Figure: 5.6 Common Expository Instructional Format

There are two important considerations about which you must be aware before designing a DOWHILE loop.

Firstly, the testing of the condition is at the beginning of the loop. This means that the programmer may need to perform some initial processing to adequately set up the condition before it can be tested.

Secondly, the only way to terminate the loop is to render the DOWHILE condition false. This means you must set up some process within the statement block which will eventually change the condition so that the condition becomes false. Failure to do this results in an endless loop.

The instructional strategy adopted *expository learning* (Figure:5.6) and *interrogatory* sections (Figure:5.7).

Instructional format articulates the learning content. It comprises many components, including *text* (Wileman,1993), *pictures/graphics*, and *symbols* (Salomon,1979; Perkins,1991; Merrill, Tennyson & Posey,1992). The new instructional material was designed to draw on the learner’s syntax and language skills (both *verbal* and *visual*) to promote understanding and to maintain the proper order of concepts. According to Gagne (1985), the words are cues in the individual’s working memory. Therefore, picking the correct instructional format was critical in providing for the acquisition of new concepts not previously encountered.

There were three types of instructional formats used, as discussed below in the following topics:

- generic text instructions
- text-only programming metaphors
- text-plus-graphical programming metaphors

2.2.1 Generic text instruction

To ensure that all participants received enough instructional content on abstract programming concepts, it was necessary to devise the introductory material as generic (*text-only*) instructions shown in Figure:5.6.
This was primarily prescriptive material, which included:

- how to proceed through the booklet
- general descriptions of the concepts
- the tutorial objectives
- task descriptions
- the summariser (Reigeluth, 1983-b)

*Expository instructional sections* that were common to both treatment booklets were represented without the addition of metaphors (Figure: 5.6).

2.2.2 Text-plus-textual metaphor

Similes and metaphors need to be understandable, despite their novelty and non-literal nature. Good metaphors are like good detective stories, with the *connotative richness of meaning* accounting for human’s ability to interpret metaphors without specific prior learning (Tversky, 1977) (Figures: 5.8 and 5.9).

Metaphors, using everyday looping functions were considered ideal instructional mechanisms to represent closely similar instances of *examples* and *non-examples* (Merrill, 1994) of programming concepts. Furthermore, they enable the learner to recognize the distinguishing features of concept instances to be executed throughout the subsequent instructional material (Gagne, 1985).
Textual metaphors (Figure:5.8) were utilized in the second exploratory study to expand Bagley's *expository instructional strategy* (Figure:5.6). In so doing, they articulated the critical attributes of the concept-to-be-learned (Merrill, 1994). In most cases, the *textual metaphor* was used after the generic textual description.

2.2.3 Text-plus-graphical metaphor

This instructional format involved the same lesson on programming logic patterns as the *text-plus-textual metaphor* format booklet. However, the *textual metaphor* was replaced with a *graphical representation* (Figure:5.9). The graphics picked to represent the *textual metaphors* were chosen by their recognisable and distinguishing (or salient) features (Figure:3.5; Figure:5.9).

They were introduced into the *instructional strategy* on the first page to visually orient the learner for the *internal/external exchange processing*.
Graphical metaphors replaced the textual metaphors, whenever possible. However, replacing the textual metaphor entirely, proved to be problematic for particular sections. For instance, replacing the sections on the comparison of the DOWHILE, and REPEAT .. UNTIL constructs with graphical metaphors was difficult. This difficulty arose because the mix of required technical information and textual metaphor were too closely aligned to enable the text to be totally removed without degrading the example (Figure:5.10).

In this case, the graphical metaphors were placed beside the relevant textual metaphors. The graphical metaphors, however, were used to completely replace the textual metaphor for the task listings.

2.3 Defining the Learning Content

The Bagley (1990) research design also enabled the isolation of the instructional strategy components, in terms of the Gagne (1985) capabilities. The cognitive capabilities are described in Chapter Four: Conditions-of-the-Learner, topic 2.1.2, Gagne capability categories. Therefore, the learning content comprised her three-self-paced lessons on PASCAL programming:

1) data types
2) program structure
3) writing new programs
Dividing the learning content into these lessons was an example of clumping as described by Mager (1988). It enables the tasks to be identified as separate learning modules. The sequencing of instructional content is described in Chapter Four: Conditions-of-the Learner, topics 2.2.1, Prerequisite learning, and 2.2.3. Instructional sequencing issues.

A learning content analysis (Merrill, 1994) revealed that the instruction targeted two types of programming concepts to be acquired, at three levels of programming knowledge:

- **basic** *(verbal informational)*
- **intermediate** *(cognitive strategies)*
- **advanced** *(procedural knowledge)*

The two types of programming concepts were:

- **concrete concepts**
- **process concepts** *(or defined / abstract)*

Behavioural analysis (Mager, 1988; Zemke & Kramlinger, 1982) identified the mental operations the learner must be capable of, in order to apply the new programming concept at higher skill levels. The instructional analysis (Merrill, 1994) identified the instructional conditions, that facilitate the learner gaining experience using the process concepts, including:

1) the characteristics of the learners
2) the instructional media
3) the levels of instructional guidance

Definition of the learning content evolved during the running of the first exploratory study, when the author observed that the participants' concentration and motivation waned as the experiment proceeded, and that the original Bagley learning content covered too many different concepts (McKay, 1999a).

2.3.1 Narrowed focus

Due to the broad nature of the Bagley PASCAL lessons, a new learning content was designed for the second exploratory study (Pilot-2), and subsequently, for the final experiment. It was developed according to the concept design strategies of Reigeluth.
Robertson (1994); and Merrill et al (1992). To ensure validity of the learning content, three experienced programmers conducted a protocol analysis of basic programming concepts:

- a computer science lecturer
- a professional programmer
- the author

They provided the programming logic patterns that were teachable in a one-hour practical tutorial session. Another task analysis of the learning content provided the sequence in which these abstract concepts were presented, including the organizational structure for the detailed presentation within each concept.

As the amount of instructional content was reduced for Pilot-2, it was easier to place an emphasis on progressing the instructional modules through the Klausmeier & Sipple (1980) Concept Learning Development (CLD) levels (see Chapter Three: Literature Review, section 2. Instructional Format).

For instance, carefully chosen metaphors were utilized as notational transfer agents (Figure:4.5). In many cases, they map directly to the critical attributes of the abstract programming concepts involved in the instructional content. Refer to Chapter Four: Conditions-of-the-Learner, sub-section 2.2 External Conditions, for the discussion on notational transfer.

2.4 Motivational Tools

Three self-paced instructional booklets were developed (see Volume: 3). The first was the Tutorial-1 booklet (9-pages), comprising the pre-instructional material for use by all the participants. The other two booklets were designed to be used in conjunction with the experiment. They are referred to as the Tutorial-2 booklets:

- Treatment-1 (13-pages) contained textual metaphors
- Treatment-2 (21-pages) contained graphical metaphors

Approximately half of the sample was given Treatment-1, with the remainder receiving Treatment-2. These instructional treatments are discussed next.

2.4.1 Self-paced pre-instructional booklet for Tutorial-1

This booklet commenced with a brief review of the introductory PASCAL lecture material. The expository content for each learning goal included: definitions, best
example, and a range of examples, non-examples, and worked examples of problems (Merrill et al., 1992).

The Tutorial-1 booklet was divided into three sections:

- the lecture review
- the examples of simple PASCAL programs and practical problems with supplied solutions
- the hands-on computer activity to access PASCAL by typing in four-simple programs

The instructional format and examples for the programming concepts in this booklet were developed drawing on Bagley (1990), Hennefeld (1989), and Savitch (1989).

2.4.2 Self-paced pre-instructional booklet for exploratory study

The learning content was developed according to the programming conventions used by Robertson (1994) for developing algorithms and pseudocode (or structured-English statements), using sequence, selection and repetition logic patterns (or programming control structures). The generic textual instruction was designed to guide learners through progressively more complex content (Bagley, 1990). Following the expository learning content a four page interrogatory section was provided to lead the learner through the instructional material and to complete the programming problems. Gaps were left intentionally in the practice examples to encourage the learner to write parts of the algorithms on their own (Figure: 5.11). Gradually, the learner creates more of the algorithms, with less information given. This fading technique was shown by Bagley (1990) to be more successful for novice programmers than for experienced programmers. The novice is encouraged to build schematic (Bobrow & Normon, 1975; Romisowski, 1981; Hummel & Holyoak, 1997) and taxonomic knowledge (Merrill et al. 1992; Merrill, 1994), that is easily transferred from both short and long-term memory (Winn, 1982-a).

Instruction commenced with a description of an algorithm. An epitome statement (Reigeluth, 1983-b), provided the tutorial objectives and instructional goals for each sub-lesson.
The learning content comprised four sub-lessons:

- **logic patterns**: (sequential, repetition, and conditional control structures)

- **repetition logic**: (using the DOWHILE and the REPEAT .. UNTIL structures)

- **comparison of the two logic patterns**

- **example problems**

Each sub-lesson defined the content to be covered. After each *expository learning section* (Figure:5.6), a *textual metaphor* provided an everyday example of the concept being taught. A short review or summariser of the four sub-lessons was given, followed by an expanded epitome statement, which was devised to lead the learner to the next part of the lesson.

Two example problems that were explained in the instruction were expressed as *textual metaphors* (Figure:5.8). The examples and the following practice problems were presented in a common instructional format (Figure:5.6). This common format involved:

- **an objective**

- **the situation description**

- **the task description that involved a six point suggested solution**

The following task headings were designed to develop *procedural knowledge*:

- **redefine the problem**
  
  (in terms of input/processing/output)

- **logic patterns**
  
  (control structures required to support the solution)

- **the repetition question**
  
  (most *novice-programmers* are unaware of the need for conceptualising this component)
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- repetition starting point
  (once again novice-programmers find this difficult)
- repetition conditional statement
- alternate repetition condition
- a suggested solution algorithm

The example problems were then followed by two more practice problems. The learning task section was presented as an **interrogatory learning format** (Figure: 5.7).

**This type of instructional format reinforces and strengthens the learner’s declarative, procedural and conceptual knowledge** (Bagley, 1990).

Suggested solutions were given in a complete form for the first practice problem (Figure: 5.11). However, the final task of writing a complete solution algorithm was left blank for the participant to finish in the second practice problem.

**Leaving gaps in this manner provides learners with an opportunity to practise their declarative knowledge.**

Progressing through the problem examples, participants could check their procedural and conceptual knowledge against the suggested solutions. This technique is known as a **coaching technique**, that points out key issues relating the problem to the definition, best examples, and non-examples (Bagley, 1990).

2.5 Validating the Learning Content

Learning content validity testing was performed on the **pretest** instrument and confirmed by independent content specialists. Variance on the **pretest** was established by **Pilot-1**, to determine scoring range for levels of prior domain knowledge: a pretest score of <28% for novice-programmers, while the experienced-programmer group’s score was recorded as =>28% from the data obtained. The lower reliability recorded by the experienced-programming group was related to the higher pretest scores, reflecting less change between the pre and post-test scores. These pretest results supported the Bagley (1990) thesis. Accordingly, the pretest met the original objective of dividing the learners who passed the pretest after taking a programming course, and were, therefore, considered experienced-programmers.


2.5.1 Conceptual learning development

To facilitate the *internal/external exchange process*, the redesigned instructional content followed Klausmeier & Sipple's (1980) CLD model (Figure:5.12). For the full description of how the CLD relates to this thesis, refer to Chapter Three: Literature Review, section 2. Instructional Format.

A *learning content analysis* was performed on the *test-items* to identify the programming concepts required to achieve a correct answer. Consequently, the *instructional outcomes*, mapped directly to CLD, may be summarised as:

- **discriminating (concrete) level:** distinguishing between different data types

- **generalising (identify) level:** knowledge of program structure and of procedure to deliver output

- **formalising the knowledge** gained from the previous levels, representing inclusive instructional outcomes, knowledge of logic patterns and knowledge of the (Bagley, 1990) six-step problem solving process.
2.6 Measurable Instructional Outcomes

A three-level graded programming skills framework was applied to the test-items. Performances on concrete and process concepts were the two categories of instructional outcomes that were measured for Pilot-1. For instance, there was an expectation that the participants would master all three concrete PASCAL concepts (char, integer, and real). However, the conceptualization of these process concepts for programming requires special instruction, to assist with the notions of the internal/external exchange process. Subsequently, the instructional outcomes reflect the matching Gagne cognitive capabilities for knowing the following:

- the order of operations/evaluation of statements
- concepts of logic flow
- use of the accumulator for totalling values
- steps to use in creating a program’s structure

<table>
<thead>
<tr>
<th>Klausmeirer’s CLD Attainment Levels</th>
<th>Definitions</th>
<th>McKay Implementation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Formal</strong></td>
<td>More than one example Observable 3-D examples Defined intrinsic and/or functional attributes</td>
<td>Cognitive Strategy</td>
</tr>
<tr>
<td><strong>discriminate between newly encountered instances</strong></td>
<td></td>
<td>Procedural knowledge</td>
</tr>
<tr>
<td><strong>Classificatory</strong></td>
<td>(Newby &amp; Stepich, 1987) Abstract concepts</td>
<td>Knows the complete “how”</td>
</tr>
<tr>
<td><strong>generalize to newly encountered example</strong></td>
<td>(Klausmeirer &amp; Sipple, 1980) Process concepts</td>
<td>Recall of simple prerequisite rules &amp; concepts</td>
</tr>
<tr>
<td><strong>Identity</strong></td>
<td>(Gagne, 1985) Concrete concepts</td>
<td>Intellectual skill</td>
</tr>
<tr>
<td><strong>recall of learned examples</strong></td>
<td></td>
<td>Discriminates: understands concepts &amp; principles</td>
</tr>
<tr>
<td><strong>Concrete</strong></td>
<td>(Merrill et al., 1992)</td>
<td>Verbal information skill</td>
</tr>
<tr>
<td><strong>recall critical attributes</strong></td>
<td>Knowing basic programming terms The Knowing of “that”</td>
<td>Declarative knowledge</td>
</tr>
<tr>
<td></td>
<td></td>
<td>States isolated rules</td>
</tr>
</tbody>
</table>

Figure: 5.12 McKay Concept Attainment Model
Furthermore, this instruction concentrated on the critical, defining, and variable attributes (Klausmeier & Sipple, 1980). For instance, in the case of the integer data type, the critical attributes were the rules associated with positive or negative whole numbers (like commas and decimal points), while instruction involving the defining attributes included other attributes of the data type, plus the critical attributes. Finally, the abstract concepts of programming constants and variables, the defining attributes, were the performance of arithmetic operations on numerical data only; or to perform the process of initialising the variable’s name. The pictures chosen for the instructional format were visual representations of these identifiable attributes (Figure:5.13).

A Test Instrument Specification Matrix was devised for the second and final experiments (Figure:5.14). The horizontal axis was used to depict the instructional objectives, with the vertical axis used for the programming content (or learning domain). Programming of logic patterns are a significant sub-division of learning within programming. The learning domain is shown here as a continuum, beginning with simple programming concepts at one end, developing into more complex conceptual programming tasks at the other. There were nine-categories of learning identified along this continuum. The instructional objectives consisted of two-categories of specific programming knowledge.

The first category was declarative knowledge: it was divided into two-levels of skill:

- **verbal information:** (knowing isolated rules)
- **intellectual:** (knowing how to discriminate between concepts and principles)
The second was *procedural knowledge*, divided into three-levels:

- **intellectual skill:** (higher-order-rules for problem solving)
- **cognitive strategy:** (recognising sub-tasks)
- **ability to integrate learning across learning domains:** (for implementing a comprehensive plan of action)

### 2.6.1 Programming knowledge performance bands (pkpb)

There were *three knowledge bands* identified to differentiate the *instructional outcomes*. There was a mix of *declarative and procedural knowledge* as the *instructional outcomes* from the *lowest* and *middle cognitive performance bands*, while *procedural knowledge* was at the top of the programming performance scale.

The *instructional outcomes* from the *lowest-pkpb* involved:

- **verbal information skill:** (knowing the basic terms and rules)
- **intellectual skill:** (understanding concepts)
- **cognitive strategy development:** (a demonstrated ability for knowledge integration)
The middle-pkp involved:

- **verbal information**: (recalling body of previously acquired concepts)
- **intellectual skill**: (a demonstrated ability to identify sub-tasks)
- **cognitive strategy**: (integrating the previous learning of higher-order rules)

The upper-pkp involved:

- **cognitive strategy**: (a demonstrated ability to understand the integration of concepts)
- **intellectual skills**: (higher-order rules including identifying sub-tasks)

2.7 Instrumentation

The assessment of cognitive performance was carried out using a pre and post-test. The pretest (used as a screening test for prior domain knowledge) was given to all participants before the instruction period. The pretest score data was used in the first exploratory study to classify the participants as novice- or experienced-programmers (Bagley, 1990).

However, in the second and final experiments, the pretest was used to determine an individual's cognitive performance by recording the difference between the pre and post-test performance.

The next topics for discussion are:

- Pretest
- Post-test
- Common test-items
- Marking strategy

2.7.1 Pretest

This test was carried out in the participants’ normal tutorial classrooms. The first exploratory study used the Bagley 10-item test for both the pre and post-tests to test six abstract concepts written to test participants' knowledge of the four-levels of Bloom’s (1956) learning taxonomy.

Consequently, it targeted the comprehension, application, analysis, and synthesis levels:
Acquisition of Programming Knowledge

- distinguishing between different data types
- demonstrating the ability to represent data types
- knowledge of program structure
- knowledge of constants and variable values
- a demonstrated ability to evaluate arithmetic expressions
- the ability to display output on the screen
- a knowledge of logic patterns
- a demonstrated ability to follow a six-step problem solving process

A new 14-item pretest was designed and calibrated (tested on a group of 47-students not likely to participate in any of the experiments), for the second exploratory experiment. This new pretest was constructed using more of the easier calibrated test-items. In order to reduce the writing-time, it was decided to pick achievable items for the beginning of the pretest. It was also hoped that this would enhance the likelihood of obtaining meaningful answers from the non-programming participants. Reducing their stress was particularly important, considering this test was administered before they received the instructional material. The more difficult items were included to identify the experienced programmers.

The instructional outcomes expected in this pretest can be described in terms of increasing levels of programming skill.

In keeping with this, there were three-levels of cognitive performance on the test-items:

- verbal information: (basic skill)
- intellectual skills: (mid-range skill)
- high-level cognitive strategies: (advanced skill)

The test-items were designed to test cognitive performance in student learning of abstract programming concepts covered by the instruction booklets. Consequently, they were directly related to program logic patterns.

However, the Pilot-2 pre-test scores were relatively high with limited variation (McKay,1999b). Therefore, the assessment instruments were again modified for the final experiment. Both the pre and post-tests were expanded to comprise 20-test-items each, representing a wider range of difficulty.
2.7.2 Post-Test

Immediately after completion of the instructional period, in each of the experiments participants were given the post-test. The difference between pre-test and post-test scores was used as the dependent variable. However, there was more emphasis placed on the mid-range skills for this test. The solution examples were measured on specific instructional content.

2.7.3 Graded skills

A three-level skills grading scheme, devised from the programming skills hierarchy (Gagne, 1985), was used to increase the range of difficulty (variance) on the pre and post-tests.

These post-test test-items were designed to target three-levels of performance outcomes:

- **Skill level-1: two-straight forward (or basic) test-items:**
  (like redefining the problem as input/processing/output concepts)

- **Skill level-2: seven-mid-range test-items:**
  (like knowing:
  † the 3-logic patterns
  † the repetition question
  † repetition starting point)

- **Skill level-3: five-advanced (or procedural knowledge) test-items:**
  (to show the depth of knowledge relating to:
  † the repetition conditional statement
  † the alternate repetition condition
  † the solution algorithm)

The lowest level test-item involved simple questions designed to elicit verbal declaration skill (knowing the basic rules). The mid-range test-item consisted of tasks which demonstrate intellectual skill (evidence of understanding the concept), while the advanced level test-item contained complicated tasks, which required integrating newly acquired programming concepts, in new situations (like writing a complete algorithm).
2.7.4 Common test-items

Two medium level test-items were used as common-items, in both the pre and post-test instruments. They were worded the same in both instruments. The only difference between them was in their placement order within the test. Their test-item positions were: seven and eight in the pretest and five and six respectively in the post-test. The later placement in the pretest reflects the emphasis to construct a more achievable instrument for participants with no apparent exposure to programming. In the post-test, these more difficult concepts were placed earlier, with fewer straightforward questions at the beginning.

2.7.5 Marking strategy

The first exploratory study employed a dichotomous scoring strategy for both the pre and post-tests. This means the test-item answers were inspected for evidence of correct programming concepts, and deemed as being either right or wrong. See Appendix for the marking scheme.

However, as the focus had shifted from the broader nature of programming per se, to a more concentrated learning programme on control logic, the test instruments for the second and final experiments employed two types of scoring strategies:

*dichotomous and partial credit*

Each test-item answer was given a numerical value of either 0, 1, 2, 3, or 4. In cases where the instructional outcome required a clear-cut answer (mostly found in verbal information), the dichotomous test-items were recorded as a 0-value or a 1-value. In cases, where there was a clear-cut division of instructional outcome (mostly found in the mid- and advanced skill ranges), a partial-credit marking strategy was implemented. These partial-credited test-items attracted either the value of: zero, 1, 2, 3 or 4. These values (scores) were then recorded to generate a computerised ASCII data file (see Volume: 2 studydat.dat).
3. Innate Environmental Factors

The bottom level of the research objectives, describes the environmental elements which affect the participation, and thereby, the outcomes of the final experiment. First, it should be noted that due to the negative experiences of self-report visualization research (Thompson, 1990), at no time did the facilitators refer to notions of learning through visualization or imagery.

The next sub-sections discuss these innate environmental elements as:

- Voluntary participation
- Sources of data
- Instructional conditions
- Experimental design
- Measurement
- Final experiment procedure

3.1 Voluntary Participation

To comply with the University’s Ethics Committee’s requirements, before inviting students to participate, they were issued with a Plain Language Research Description Document, which gave a brief overview of:

- the purpose for conducting the research
- the sequencing of the experiment’s stages (tests and instruction period)
- confidentiality issues
- notification that their participation was strictly voluntary

In each experiment a small number of participants did not complete all stages of the experiment. The reasons given for not completing ranged from disinterest with the learning content or a lack of identified relevance, to having another appointment elsewhere. These reasons may be rationalised in terms of the requirement for a suitable attitude (Gagne learning capability) towards learning. However, the remaining participants were very keen to finish all stages, thereby demonstrating that their attitude was sufficient to motivate their interest through each stage of the experiment.
3.2 Sources of Data

A total of 276-undergraduate business students participated in the three experiments (Pilot-1 (37); Pilot-2 (45); Final Experiment (194)), with each sample drawn from one particular information technology service subject, which delivers introductory database instruction and caters for a broad range of students. They were enrolled in a Bachelor of Business degree at an Australian University (they were not information technology students). Many of them had no previous computer-programming experience. (See Chapter Five: section 1.2 Building the Context, for a discussion on the sample profile).

The sample was grouped, using their Verbal-Imagery Cognitive Style Analysis (CSA) ratio, to identify pairs of similar cognitive style. (See Chapter Two: topic 4.3.3 for the description of the CSA.) These pairs were then split to receive the instructional treatment booklet, with Treatment-1 being the text-plus-textual metaphor format, and Treatment-2 comprising the text-plus-graphical metaphors.

3.3 Instructional Conditions

The instructional conditions involved two distinct components:

- learning content:
  - programming logic flow concepts
- instructional events:
  - pre-instructional events .. to provide context
  - the experiment .. the research data

A number of changes were made to the sequencing of pre-instruction strategy, prior to conducting Pilot-2, and the final experiment. (The learning content and instructional conditions were therefore radically different from Pilot-1; see section 2.3 Defining the Learning Content, 2.3.1 Narrowed focus).

The delivery method for the instructional events was changed to involve separate components:

- a one-hour lecture
- two 2-hour practical tutorial sessions, held one week apart

Changes were made to the sequencing of pre-instructional events involving the timing of the introductory lecture and Tutorial-1. The introductory lecture was run two to three weeks before the final experiment (Tutorial-2) to reduce the risk from the possible associations made between the new information given during this lecture, and the elaborative effect (Woloshyn, Wood & Willoughby, 1994) of the pretest test-items.
Consequently, this lengthened the total duration of the experimental components by a fortnight, requiring one month to complete the full study.

3.3.1 Pre-instructional events

Due to the reduction in learning content, it was necessary to present the minimum number of programming concepts in the pre-instructional lecture. This delivery technique equates to a Gagne type of verbal informational session, whereby the lecturer only gives facts and rules. Introducing the concepts of programming in this manner provided the participants with the potential to progress through the lower stages of the CLD (discriminating and generalising equivalents across different contexts) (Klausmeier & Sipple, 1980). Subsequent experience of the first practical learning session (Tutorial-1), justified progress to the higher levels of the CLD (Figure: 5.12), thereby taking a wholistic approach to the design of the instructional conditions.

3.3.1 (a) One-hour lecture

To enable the participants to work on their own, in both of the subsequent two-hour tutorials, an introductory one-hour lecture was designed, involving:

- why PASCAL was chosen
- data types
- PASCAL structure
- input/output issues
- a brief outline on control structures

3.3.1 (b) Tutorial-1

The learning content for this tutorial was considered as a pre-instructional event, and was designed to assist the participants in developing a positive attitude towards the programming environment. Therefore, the instructional components involved:

- a revision of the lecture material (especially relevant for participants who may have missed the earlier 1-hour lecture), as familiarisation with PASCAL data types
- accessing the PASCAL editor on the University’s network
3.4 Experimental Design

A possible 2 x 2 factorial design (Gay, 1992) is shown in Figure:5.15. However, ANOVA was considered inappropriate (Izard, 1999). The extent of the design effect was unknown. As a result, simple random sample statistics could not be used.

The CSA was conducted before the experiment. Furthermore, it was decided to use another statistical measurement tool better suited to analyse the test data for cognitive performance. Since the research questions were interested in the magnitude of effect, the Cohen (1977) approach was used instead of ANOVA.

3.5 Measurement

The cognitive performance was, therefore, measured using the QUEST Interactive Test Analysis System. Given that in both cases, the number of participants and the tested instructional outcomes (see Volume: 3 Calibration of Testing Instrumentation) had increased since the second exploratory study, it was now possible to plan for a more thorough data analysis of the interacting independent variables (instructional format/cognitive style) (Figure:5.15), with the dependent variable (cognitive performance of the instructional outcomes).
Central to this thesis, will be the ability to establish the relationship between cognitive performance and instructional outcome.

Therefore, both these topics will be discussed next.

3.5.1 Cognitive performance

In order to evaluate the performance of each participant, the QUEST Interactive Test Analysis System (Adams & Khoo, 1996) was used. This test measurement application allows for improved analyses of an individual’s performance relative to other participants. This program establishes a model, which allows the best estimate of the probability of an individual making a certain response to a test-item. In addition, it estimates test-item characteristics. For a full description of QUEST and its capabilities, see Adams & Khoo (1996), and Izard (1995).

As measuring cognitive performance was crucial to this dissertation, it is necessary to separate out the following sub-topics for discussion:

- Assessment of cognitive skills
- Scaling the performance
- Test review process and assessment validity

3.5.1 (a) Assessment of cognitive skills

The classical approach to assessment identifies test-items which do not distinguish between high and low scores, whereas QUEST relies on a type of assessment that is similar to a criterion measure. According to Griffin & Nix (1991:264), this means an observation is:

"directly compared to a single, fixed level of performance, or pre-specified criterion, and is interpreted as either mastery or non-mastery"

It is now possible to look at a QUEST Variable Map to determine the behaviour of test-items and participants (or cases), compared to each other. Reviewing the QUEST Item-fit Map enables a designer to check for unexpected results. Furthermore, examination of the QUEST Fit t-values (see Appendix for the Test-Item Estimates Table) empowers a designer to either reject unstable test-items or include additional test-items.
3.5.1 (b) Scaling the performance

Item Response Theory (IRT) describes the assessment method used by QUEST. It compares actual patterns of responses from the interactions of test-items with participants compared with a model pattern. This becomes the fit-statistic. Unusual patterns can be investigated. Central to QUEST is a measurement model developed in 1960 by a Danish statistician called Georg Rasch. QUEST develops an unidimensional scale with equal intervals along each axis, to measure performance and test-items together. This scaling feature enables a developmental sequence of learning tasks to be arranged from simple to more complex. It is also possible to locate an individual at different skill levels along this scale. The assessment of particular skill levels relies on choosing tasks that can provide evidence, which effectively distinguishes between those who have the required knowledge and those who have not.

3.5.1 (c) Test review process and assessment validity

Test-item analysis results in allowing instructional strategy decisions to be made about the validity of the test-items: either to retain, modify, or discard. This forms the basis of a test blueprint (or specification) of the testing instrument. The associated Test-item Specification Grid (an instructional design tool which places learning tasks and instructional objectives in a matrix) must show enough items remain to give a range of test-item difficulties within each cell (Figure:5.14). These decisions fall into three categories (Izard, 1995):

- too easy, wrong choice, or not possible
- may not discriminate, correct choice too obvious
- may be too difficult, or more than one answer is correct

3.5.2 Instructional outcomes

Evidence of a weak variation of overall performance emerged from the results of Pilot-2. Consequently, the testing instrumentation was changed again, to include a larger number of test-items in each of the instructional outcome categories. Examination of the Test Instrument Specification Matrix (Figure:5.14), revealed a number of areas where the combination of instructional objectives and learning content were not included in the earlier testing instruments.

This meant there was a bunching effect of test-items at either end of the programming difficulty scale. For instance, too many basic test-items, which may
account for the lack of variance in performance outcomes in the two exploratory studies. Consequently, both the pre and post-tests were increased from 14-test-items in Pilot-2 to 20-test-items in the final exploratory study, to provide for a broader range of instructional outcomes.

3.5.2 (a) Validity

The new test-items were calibrated manually (See Volume: 3 Calibration of Testing Instrumentation). They were tested on a sample of first year students (not likely to participate in the experiment). The calibration of these new test-items was necessary to ensure consistency with the existing test-items used successfully in Pilot-2.

Again there were three-levels of performance on the pre and post-tests:

- **basic** (verbal information)
- **mid-range** (intellectual skills)
- **advanced** (high-level cognitive strategies)

There were six-new test-items added to each test instrument for the final experiment. The programming knowledge levels of these new test-items included:

- two-basic level
- two-mid-range
- two-advanced

To facilitate the measurement of cognitive performance, some of the test-items were used in both the pre and post-tests. In all, there were 8-common test-items. These common test-items were designed to flush out specific instructional outcomes that were directly linked to the critical attributes identified in the instructional metaphors. The emphasis of the instructional outcomes on the post-test also shifted to concentrate on the mid-range and advanced instructional (performance) outcomes.

The same combination of dichotomous and partial credit scoring methodology was used. It has been shown that this type of scoring methodology is more appropriate for evaluation of the differences in cognitive performance levels.
3.6 Final Experimental Procedure

The final experiment was conducted in week-10 of the academic semester. Overall, there were a total of 11-tutorial groups participating. As before, each treatment group was separated for the duration of the experiment. A monitor observed the participants throughout. Due to the voluntary nature of the involvement, if any participant wished to withdraw (for any reason), this was permitted. Consequently, there were a small number (four-participants) who did not complete the full experiment. The attrition was due partly to the voluntary nature of the participation, and to a belief that programming concepts would not be included in the final exam for the subject.

3.6.1 Screening Tests

It was necessary to categorize the participants according to two characteristics: their levels of prior knowledge of computer programming, and their cognitive style. This categorical data was again gathered before each of the experiment's instructional periods.

3.6.1 (a) Cognitive style

Within the framework of the internal/external conditions-of-the-learner, the Riding & Cheema (1991) cognitive style construct has proved to be a useful cognitive modelling tool. Therefore, the position of the participants on the Verbal-Imagery and Wholist-Analytic dimensions was identified, using the computer-presented CSA (see Chapter Two: Conceptual Framework, topic 4.3.3 Cognitive style measurement).

The only change to the screening for cognitive style was to alter the location from a private room to the normal classroom. Therefore, the CSA was conducted during each Tutorial-1 session. This was necessary due to the inconvenience of running separate screening tests on a large number of individuals. To further reduce the time for this process, two computers were set up with the CSA software at the back of the classroom (a computer laboratory). Participants were called to the back of the tutorial classroom (two at a time). They took the cognitive screening test, sitting at computers on opposite sides of the room. These computers were positioned such that the rest of the class could not view their screens.

3.6.1 (b) Pretest

This was conducted at the beginning of Tutorial-2 to determine levels of prior domain knowledge. It was carried out in the participants' normal tutorial
classrooms. The pretest was constructed using more of the easier pre-trialed test-items. In order to reduce the writing-time, it was decided to pick achievable items for the beginning of the pretest. It was also hoped that this would enhance the likelihood of obtaining meaningful answers from the non-programming participants. Reducing their stress was particularly important, considering this test was administered prior to them receiving the instructional material. The more difficult items were included to identify the experienced programmers.

3.6.2 One-hour lecture

The lecture was given earlier in the semester (week-7), to reduce the likelihood of creating a ceiling effect (a possible reason for many high performing results on the Pilot-1 and Pilot-2 pretests).

3.6.3 Instructional period

This instructional event involved the running of the actual experiment. At no time were the participants given any explanation as to the likelihood of differences in instructional strategies. They were, however, reminded that the skills gained during the experiment would be transferable to other contexts in other tertiary level subjects.

Although there was no official recording of the test results in the normal assessment for the participants, they were advised that the (general) knowledge they gained would be useful in completing the higher-grades of their database assignment for the subject.

There were no changes made to the instructional content for the final experiment, with the learning content remaining exactly the same as Pilot-2. However, there were changes made to the timing or sequencing of the pre-instructional activities.

3.6.4 Cognitive performance

Each participant was given the post-test on completion of the self-paced instructional booklet, in Tutorial-2. The conditions for this test were the same as Pilot-2 (see McKay,1999b), with test modifications as described previously. The purpose of this test was to identify improvement in cognitive performance from the pre-test scores obtained prior to the instruction period.
Summary

The experimental design focussed on the strategic knowledge requirements for the acquisition of complex programming concepts in a computer-mediated environment (Figure:5.1). Major influencing factors were shown to be: type of content, existing knowledge, and the students' information processing ability. This design validates and exemplifies the three level knowledge acquisition framework deduced from the selected research methodology.

The first level, defined the research process necessary to construct the context for conducting the study (Figure:5.2). The scope of the research was threefold: to determine the specific knowledge requirements for the acquisition of programming concepts (Figure:5.3), to identify the cognitive strategies employed by novice-programmers, and to develop the theoretical foundations to support a model for describing meta-knowledge acquisition, in particular for the acquisition of complex programming concepts. The key research parameters were shown to involve two distinct components involving the external-conditions-of-the-learner, namely: the method of delivery (relating to the learning content, instructional conditions, presentation mode, and specific learner characteristics), and the measurable instructional outcomes (MIOs) (relating to the instructional method and cognitive style construct).

The second level, specified the nature of the variables involved in the interaction of cognitive style and instructional strategies and described the research parameters for the acquisition of programming knowledge (Figure:5.5). Sampling adequacy of the learning content was pre-determined to ensure content validity. The instructional mechanisms employed to draw out the specific programming performance expectations were shown to be grounded in instructional design principles (Klausmeier & Sipple,1980, Gagne,1985, Merrill et al.,1992). A concept attainment model (Figure:5.12), was devised to formalise the range of programming knowledge performances, as MIOs (Figure:5.14). The QUEST Interactive Test Analysis System provides a measuring tool, which ensures an absence of error measurement in the measuring instrument. Therefore, reliability of the test instrument is assured through the calibration techniques utilized by the QUEST estimate, thereby validating the statistical basis of the research design. Replication of the results is possible through the relative absence of the distortions otherwise encountered with observational techniques.

The third level described the final experiment, setting out the limitations of the environmental factors which may affect results, including: voluntary participation, sources of data, instructional conditions, experimental design, and measurement.
The next chapter presents the analysis of results using the third level of the knowledge framework described above.
This chapter presents the analysis of results within the third level of research objectives, described earlier as the innate environmental factors which impact on cognitive performance. The discussion commences with hypotheses developed to test for evidence of whether the research objectives have been met.

The exploratory studies are reviewed first, followed by the description of the four hypotheses designed to disambiguate the environmental elements on the findings.

Factors affecting results are presented in a tabular format, while the measurement of cognitive performance, and details of the respective data analysis methods, provide the statistical evidence in support of the final experiment.

As presented in the previous chapter, there were three separate experiments conducted (two exploratory studies and the final experiment). The two exploratory studies were conducted on a relatively small sample to identify possible deficiencies in the experimental design, and to limit any confounding factors, which may interfere with the interaction of the research variables. Whereas, the modifications made to the final experiment were presented in the previous chapter, the factors affecting results are described in Table:6A. The small sample size in the exploratory studies limited the data analysis to the single category of cognitive style (SCCS) groupings (Verbalizers/Imagers), which clearly indicated that:

*Verbalizers achieved the overall best performance, when given graphics enhanced instructional material.*
Analysis of the *Imager* results is not as clear, with some evidence suggesting that:

*Imagers may perform better with a text-only treatment.*

The final experiment confirmed these findings and also revealed that:

*Wholists given graphic enhanced material outperform both their text-only counterparts, and Analytics, given either treatment type.*

More importantly however, the population of 194-participants for the final experiment allowed for an analysis of the interactive effect of the two dimensions of cognitive style (referred to as the *integrated cognitive style* (*ICS*) sub-groups). The findings that emerge from this analysis shows the importance of considering both dimensions of cognitive style when evaluating potential for knowledge acquisition. Given the results from the exploratory studies, one would expect the *Wholist-Verbalizer* receiving *graphics enhanced* instructional material would clearly outperform other treatment sub-groups. However, it is evident that:

*Wholist-Imagers and Analytic-Verbalizers, with the graphics enhanced instructional material, were the best performing sub-groups on the final experiment.*

Moreover, as expected from the exploratory study results;

*The two Analytic-Imager sub-groups are the poorest performers, with the graphics-enhanced treatment group performing worst.*

The increased number of participants, and the modifications made for the final experiment, also provided the opportunity for improved measurement of participants' performance.

**Comparison of a participant's cognitive performance relative to other participants, and relative to the test-items, was implemented using the common-QUEST logit scale-(Qls) (see Chapter Five : Research Methodology and Experimental Design, sub-section 3.5 Measurement).** The *test-items* were graded, from simple programming concepts to more complex programming tasks, up the *Qls in programming knowledge performance bands* (*pkpb*). In this way, the probability of a participant reaching a specific knowledge level, after completing the instructional material can be determined. A further analysis of relative movement between knowledge levels was conducted.
A means analysis of the QUEST data was also conducted in three stages, to measure the effect of cognitive style and instructional treatment on cognitive performance:

- testing for effect of instructional treatment
- testing for effect of cognitive style
- testing for the interactive effect of instructional treatment and cognitive style

The means analysis indicates the following:

- The effect size (ES) (Cohen, 1977), of instructional treatment on cognitive performance, for the acquisition of programming knowledge is generally small with a maximum statistical power of 45%.

- The ES of cognitive style on performance is small to medium with a couple of large ES comparisons, which give a statistical power of over 80%.

- The interactive ES of instructional treatment and cognitive style on performance is predominantly medium to large (nine of 16-analyses) with four analyses having a statistical power over 75%, and approximately half of the analyses over 50%.

- Gender appears to have little or no affect on cognitive performance.

In summary, the final experiment indicates:

- the importance of utilising the full integrated cognitive style dimensions when evaluating knowledge acquisition potential
- the value of the QUEST logit scale in measuring cognitive performance and knowledge acquisition
- that there is a significant interactive effect of instructional treatment and cognitive style on programming knowledge acquisition
Chapter Six : Results

The basis for these claims is now presented in detail in the following sections:

- Hypotheses
- Factors affecting results
- Tools and analysis
- Results - final experiment
- Summary

1. Hypotheses

The main research hypothesis evolved as the doctoral programme progressed, informed by the results from the exploratory studies and modifications to the final experiment, thereby challenging prior assumptions, having regard to the principal research question:

**Does the interaction of instructional format and the cognitive style construct affect the acquisition of abstract programming concepts?**

The first exploratory study was a modification of Bagley's (1990) experiment, using her structured format instructional booklet as *Treatment-1*, with the addition of graphical representations (see Figure:5.13) for *Treatment-2* (see Volume: 3).

Based on the findings of Douglas & Riding (1993) and O'Halloran & Gauvin (1994), expectations were:

that Verbalizers would perform best with the text-only instructional material and that Imagers would perform best with the graphics-enhanced material.

However, as Figure:6.1-a illustrates, the Verbalizers, using the text-plus-graphics material achieved the best performance, and the Imagers performed better, when given the text-only material. A full description of the first exploratory study is presented in McKay (1999a).
Based on the results of Pilot-1, and with the modifications to the experimental design, that were made prior to the second exploratory study, it was expected that:

**Verbalizers** will learn new programming concepts best with a **text-plus-graphical metaphor** instructional format. They will be better at transferring their conceptualizations of the graphical representations into new computing contexts than the **Imagers**. **Imagers** may perform better with a **text-plus-textual metaphor** treatment than with **graphics enhanced material**.

The second exploratory study confirmed the first supposition, that **Verbalizers** given a **text-plus-textual metaphor** treatment achieve the highest overall score (Figure:6.1-b). However, the **Imagers** performed better with the **graphics enhanced instructional material** (see McKay (1999b) for a full description of Pilot-2).

This apparent contradiction in results between **Imagers** in Pilot-1 and Pilot-2, required examination prior to proceeding to the final experiment:

- **The effect of secondary factors relating to the experimental design needed to be limited. These factors will be discussed in Chapter Seven : Meta-Knowledge Acquisition Process, section 2. Implementing the Research.**
The narrow range in *test-scores* (apparent in Pilot-2) left little room for differentiation of *post-test performance*. The *QUEST Interactive Analysis System* (Adams & Khoo, 1996), was chosen to evaluate *participants' performance*, relative to each other, and relative to the *test-items*. There will be a brief discussion on *QUEST*, section 3. Tools and Analysis, within this current chapter.

The exploratory studies focussed on the *cognitive style dimension* (Riding & Cheema, 1991) that describes how an individual may *represent information during thinking* (*Verbalizer-Imager*). The contradiction in the *Imagers' results* may be due to the interaction of the second *cognitive style dimension*, which defines *the individuals' mode of processing information* (*Wholist-Analytic*). In order to analyze the effect of the *Wholist-Analytic dimension* on programming performance, the data from the two exploratory studies was re-grouped and analyzed (Figure:6.2).
Hypotheses

Analysis of the Wholist-Analytic cognitive style dimension, showed similar results to the Verbalizer-Imager grouping. In both exploratory studies, Wholists with the graphics enhanced instructional treatment were the highest performing group, matching the Verbalizers' performance. Although Analytics with the graphics material outperformed their textual counterparts in both studies, the difference in means is much less than with the Wholists.

Based on the findings of the two exploratory studies, a series of assumptions were formed for the final experiment. The first hypothesis was a general statement covering the overall purpose of the study:

\[ H_1 \text{ Instructional treatment will have an effect on the cognitive performance of one cognitive style group compared to another.} \]

In order to analyse the effects of instructional treatment, and the cognitive style construct (Verbalizer-Imager; Wholist-Analytic), it would be necessary to conduct separate comparisons of each independent variable. Consequently, the second hypothesis examined whether the effects of instructional format will be different for a particular group of individuals?

\[ H_2 \text{ Cognitive performance is affected by the type of instructional treatment they receive.} \]

It was expected that instructional outcomes would be different for particular combinations of the cognitive style construct. For instance: Wholist-Verbalizers given the text-plus-graphical metaphor treatment would be expected to perform much better than their textual metaphor counterparts.

The effect of the second independent variable (cognitive style) on cognitive performance also had to be analyzed separately. The third hypothesis examined the effects of the cognitive style construct on instructional outcome.

\[ H_3 \text{ Cognitive performance will be affected by the individual's cognitive style.} \]

Consequently, expectations were that Wholists and Verbalizers using the graphical metaphor treatment would perform better than an Analytic or Imager using the same treatment. Therefore, a Wholist-Verbalizer should perform much better than an Analytic-
Imager, given this treatment. Conversely, the expectations for the textual metaphor treatment are not clear, with the two pilot studies showing opposite trends.

Finally, to complete the analysis of the interactive effect of instructional treatment and cognitive style on the acquisition of abstract programming concepts, an investigation of the interaction of cognitive style and instructional format was necessary.

\[ \text{H4 Cognitive performance will be affected by the interaction of cognitive style with the type of instructional treatment.} \]

For instance: it was expected that a Wholist or Verbalizer given the graphical metaphor treatment would outperform an Analytic or Imager using the textual metaphor treatment. Furthermore, a Wholist-Verbalizer using the graphical treatment should perform better than an Analytic-Imager using the text-only material.

2. Factors Affecting Results

One of the main purposes of the exploratory studies was to identify any extraneous variables, which may influence the experimental results. Table:6A lists the factors identified and the modifications made to the final experiment to limit their effect.
## Table: 6A Factors Affecting Results

<table>
<thead>
<tr>
<th>Factor</th>
<th>Description</th>
<th>Observation</th>
<th>Final Experiment Modification</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sample Size</strong></td>
<td>The small sample size reduces the statistical validity of the results and limits analysis of the interaction of the two-cognitive style.</td>
<td>Pilot-1 41-participants</td>
<td>Increased sample size to approximately 200-participants.</td>
</tr>
<tr>
<td><strong>Total Population</strong></td>
<td>It was not possible to test for the declarative and / or procedural programming knowledge identified in the Test Instrument Specification Matrix.</td>
<td>Pilot-2 28-participants</td>
<td>Therefore a clearer relationship between the dependent variable (test performance) and the independent variables, instructional format (text-only/text-plus-graphics) and cognitive style (Verbal/Imagery and Wholist/Analytic), would be expected with the larger sample size.</td>
</tr>
<tr>
<td><strong>Attrition</strong></td>
<td>Due to the length (8-hours) of the exploratory workshop, many participants failed to complete the experiment.</td>
<td>Pilot-1</td>
<td>Reduced the experiment to a 2-hour tutorial session.</td>
</tr>
<tr>
<td><strong>Participant Fatigue</strong></td>
<td>Of those who completed the instruction period, several participants performed poorly on the post-test, due to fatigue.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Language &amp; Cultural Differences</strong></td>
<td>The wording of the learning content, in the instructional booklets and tests were written for an American population (Bagley,1990), which may have had a minor effect on the Australian/Asian participants.</td>
<td>Pilot-1</td>
<td>The learning content for Pilot-2 and final experiment were written by the author, using Australian English and programming metaphors.</td>
</tr>
<tr>
<td><strong>Concept Testing</strong></td>
<td>Too many programming concepts (61) were contained in the Pilot-1 test. Controlling for extraneous variables, such as anxiety and boredom, was too complex.</td>
<td>Pilot-1</td>
<td>Reduced the: number of learning goals, time-in-instruction, and number and type of programming concepts-to-be-learned.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>A further experiment was needed to determine what the interactive relationship is between instructional format and cognitive style. A new experiment was needed to test the finding that Verbalizers perform best with text-plus graphically enhanced instructional materials; and the Imagers perform best with a text-only instructional format.</td>
</tr>
<tr>
<td><strong>Variance</strong></td>
<td>The Pilot-2 tests did not have enough concepts or range in difficulty, resulting in only a small variance in participants' performance.</td>
<td>Pilot-2</td>
<td>The final experiment test instruments included more test-items with an increase in medium and high difficulty questions.</td>
</tr>
<tr>
<td><strong>Ceiling Effect</strong></td>
<td>With the pre-experiment lecture and tutorial directly preceeding the pre-test and instructional period, pre-test scores were relatively high, limiting room for an improved performance on the post-test.</td>
<td>Pilot-1 24-participants</td>
<td>To limit the freshness of their cognitive strategies; a reduction of the pre-experiment information and an increase in the time between the pre-instructional strategies (introduction lecture/tutorial-1), and the experiment (tutorial-2: pre-test, instructional period).</td>
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3. Tools and Analysis

The measurement of cognitive performance is a complex issue, for which quantitative analysis is difficult. QUEST allows for evaluation of a participant's performance relative to others, and estimates their level of knowledge acquisition, relative to the required instructional outcomes. A means analysis of the QUEST data, using effect size and statistical power further quantifies the significance of the findings.

The following sub-sections will briefly review:

- QUEST measurement tools
- Data analysis methods

3.1 QUEST Measurement Tools

The QUEST Interactive Analysis System contains a series of output displays, which provide for visual and quantitative analysis of the data. Central to the QUEST measurement system is the uni-dimensional logit scale (Qls).

3.1.1 QUEST logit scales

The QUEST system measures a participant's ability and test-item difficulty as mathematical units expressed as logits (Wright & Stone, 1979:17). See Appendix for QUEST Participant (Case) Estimate Table.

"A person's ability in logits is their natural log odds for succeeding on items of the kind chosen to define the 'zero' point on the scale. And an item's difficulty in logits is its natural log odds for eliciting failure from persons with 'zero' ability"

A participant-logit of zero means they achieved 50% of the test-items. Therefore, a positive-participant-logit (>0), means that they achieved greater than 50% correct answers, while a negative-participant-logit means they achieved less than 50%. Poor performers will be at the bottom of the Qls, and high performers, who have a higher probability of answering difficult test-items, will be towards the top of the scale.

A test-item-logit of zero means that 50% of the participants achieved that task level. A positive score (>0), means that less than 50% of them reached the required instructional outcome, and a negative score, means that greater than 50% had correct answers for that test-item. Therefore, a positive-test-item-logit reflects a poorly answered question, and a negative-test-item-logit, a well answered question.
Simple programming tasks will fall at the lower end of the scale, where the majority of participants have a high probability of achieving the required instructional outcome. More complex test-items will be at the top of the Qls, possibly beyond the reach of any of the participants.

3.1.2 QUEST output displays

The main visual output display of QUEST, is the Variable Map. Figure:6.3 illustrates the post-test performance of participants in the second exploratory study.

The overall successful responses to the post-test test-items, shows that 50% of the participants were able to achieve the overall required programming tasks. This indicates that the testing instrument may have been limiting in its ability to differentiate individual performance. However, a more detailed analysis of the QUEST Variable Map (Figure:6.3), shows that the top three and seven of the top 11-performers had the text-plus-graphical metaphor treatment.
Figure: 6.4 QUEST Post-Test Test-Item Fit Map

The largest single group within these high performers, was the Verbalizers (five participants) using the text-plus-graphical material (see them as O’s on the Variable Map).

Consequently, the QUEST analysis supports the statistical findings. It shows that Verbalisers using the text-plus-graphical metaphor treatment were likely to perform better than the other three groups.

A second QUEST visual display is called an Item Fit Map. The Fit Map evaluates the test-items, and identifies any unpredicted responses using a statistical effect size approach to determine fit. If a test-item is behaving in a consistent manner to the rest of the test-items (measures the same cognitive construct), it should fall within the two dotted lines (see Figure:6.4). Therefore, test-items which fall outside of the Sd, measure something else. For instance, a relatively simple test-item, which participants were unable to answer, may indicate a lack of clarity with the wording of the test-item.

The Test-Item Fit Map for the second exploratory study is shown in Figure:6.4. The map displays two unpredictable test-items, number Post3 and Post5. The latter was a common test-item (pre and post-test), identified as pretest test-item-7. In the post-test, this test-item should have been answered correctly. However, the 1.6 fit value does not indicate this. Consequently, this test-item was modified for the final experiment. On the other hand, common test-item Pre8Post6 shows a predictable response fit to the Rasch model (Griffin & Nix,1991), with a 0.71 value. See Appendix for QUEST Estimates (Thresholds) and Item Analysis Tables.
The third key display from QUEST is the Kid Map, which shows an individual's performance relative to the test-items. Figure:6.5 shows a typical Kid Map also taken from Pilot-2. The heading provides the individual's group and scale combination used in the estimation, the logit-ability, fit statistic, and percentage score achieved. The vertical scale represents the common-Qls, with the test-items plotted according to
difficulty level. Test-items are displayed using an \( x.y \) matrix, where \( x \) = the test-item number, \( y \) = test-item level.

Test-items achieved are plotted on the left side of the Kid Map, while on the right if not. A participant's pattern of response conforms to the Rasch model, when there is an expectation that the majority of test-items below the ability estimate (or logit value shown as XXX) are displayed on the left side of the Kid Map, with the majority above the ability estimate on the right (Adams & Khoo, 1995).

3.2 Data Analysis Methods

The data analysis will focus on the post-test performance of the cognitive style groups. The \( Qlv \) will be the measure of this performance. In order to compare performance between cognitive style groups, separate QUEST-estimates have been run for each group. However, it is the participants' position on the common-Qls (All-on-Post-test) that will be analysed. The separate sub-group estimates have been used to analyse which test-items were answered differently by which sub-group (see sub-topic 4.2.3 (b)). For the discussion on how the sub-groups were formed, see Chapter Five : Research Methodology and Experimental Design, sub-section 3.4; and Chapter Six : Results, topic 4.1.1 Cognitive styles measure.

To measure improved performance, and minimize effects of programming prior domain knowledge, each individual participant's QUEST-pretest-logit-value \( (Qprelv) \) has been subtracted from their QUEST-post-test-logit-value \( (Qpostlv) \) now referred to as the QUEST-difference-logit-value \( (Qdlv) \). The population was divided for analysis using Riding's 2-dimensions of cognitive style and instructional treatment.

The first-pass-analysis, split the population into approximately half, using the Wholist-Analytic and Verbal-Imagery dimensions separately. In other words, the analysis was conducted on the Wholist, Analytic, Verbalizer, and Imagery groups, referred to as the single-category-of cognitive-style (SCCS) groups. The second-pass-analysis, divides the population into quarters, integrating the two continua of Riding & Rayner's cognitive style construct. These sub-groups will be referred to as the integrated-cognitive-style (ICS) sub-groups: Wholist-Verbalizers, Analytic-Verbalizers, Wholist-Imagers and Analytic-Imagers.

The data analysis has been conducted in two stages. The first-stage is a means analysis, for the SCCS groups and ICS sub-groups, on the common-QUEST scale (cQs). This has been performed for the \( Qprelv \)'s, and the \( Qdlv \). SPSS box-plots of the SCCS groups and ICS sub-groups have been created to show the median, data spread and any outliers.

The second-stage of analysis, involved dividing the Qls into programming-knowledge-performance-bands (pkpb's), with each pkpb spanning 0.5 on the cQs. The number and percentage of each SCCS group and ICS sub-group within each pkpb was then calculated. The difference between the number of participants in each pkpb on the post-test and pretest...
was calculated, with the majority of the trends observed in the means analysis (see topic 4.2.2) also present in the pkpb evaluation (see topic 4.2.3). Analysis of the pkpb's, in relation to the test-item instructional outcomes was then conducted. Individual QUEST-Kid-Maps of participants' performance varied between the pre and post-test. They are reviewed below in 4.2.3 (a) (ii) Integrated-cognitive-style (ICS) sub-groups.

A gender analysis (see topic 4.2.4) was conducted looking at the interaction of instructional treatment and Riding's 2-dimensions of cognitive-style. An analysis of the ICS sub-groups (For example: Wholist-Verbalizers) was not conducted, due to the small number of participants within each sub-group.

3.2.1 Statistical power analysis

The main analytical tool for evaluating the QUEST data, was statistical power analysis; a means analysis technique, based on testing the probability of a null hypothesis being incorrect.

For instance: the main null hypothesis for the study was:

\[ H_1 \text{ Instructional treatment will have no effect on the cognitive performance of one cognitive style group compared to another.} \]

Or in other words, the mean-Qdlv for Verbalizers using Treatment-1, should be approximately equal to the mean-Qdlv of the Verbalizers using Treatment-2. The effect size (ES) (Cohen,1977) has been calculated.

The formula for calculating the ES is:

\[ \text{ES} = \frac{|M_a - M_b|}{S_d}; \text{where the nominator is the absolute value of the difference between the mean-Qlv of the first sample group (Ma), and the second sample group (Mb). The denominator is the combined standard deviation of the two groups (Sd).} \]

Several interesting trends can be identified from this analysis. These results will be discussed within topic 4.2.2.
Table: 6B shows the qualitative effect of the independent variable being tested, relative to the dependent variable, the mean-Qdlv, based on ranges in the ES. The Table also gives the range in probability of rejecting the null hypothesis, based on two sample sizes, approximating the SCCS groups and ICS sub-groups.

For a significance-criterion (a2) of 0.10, the approximate statistical-power-range for the two sets of analyses: the SCCS groups and the ICS sub-groups are also listed in Table: 6B (see Appendix for Cohen,1977:30 Table 2.3.2).

The a2, is the risk of mistakenly rejecting the null hypothesis.

In this analysis, we are willing to accept a 10% chance of incorrectly rejecting the true null hypothesis. The power of a statistical test of a null hypothesis is defined as the probability that it will lead to the rejection of a null hypothesis (Cohen,1977)
4. Final Experiment

The final experiment was based on the Pilot-2 methodology with a few minor changes to correct for recognised deficiencies (See Table:6A). Firstly, the pre-instructional material was reduced, and the pretest expanded in order to lower pretest scores, thereby allowing for increased differentiation of post-test results. To further differentiate performance, test-item responses were measured using a combination of dichotomous and partial credit scoring, rather than dichotomous only. Finally, the sample size was increased to over 190-participants, allowing statistical analysis of the ICS sub-groups. (See also Chapter Five: sections 1.2 Building the Context, for a discussion on the sample profile and 3.2 Sources of Data).

The following sub-sections include:

- Screening tests
- Post-test performance and analysis
- Factors affecting results

4.1 Screening Tests

As with the previous pilot studies, the Cognitive Style Analysis (CSA) ratio was used as an independent variable to split the population into sub-groups (see Chapter Two : Conceptual Framework, topic 4.3.3 Cognitive style measurement), and the pretest was used to limit the effects of prior domain knowledge of computer programming on the post-test results.

4.1.1 Cognitive styles measure

A total of 199-participants completed the CSA. Their Wholist-Analytic (W:A) ratio values ranged from 0.65 to 3.43; whereas, their Verbal-Imagery (V:I) ratio ranged from 0.68 to 1.94. Due to the increased participant numbers, both ratios were used to split the data for analysis. The W:A ratio of 1.20 was used to identify the Wholists and Analytics. As with the 2-pilot studies, a V:I ratio of 1.05 was used to define the Verbalizers and Imagers (Figure:6.6).

4.1.2 Pretest performance and analysis

A total of 195-participants completed the pretest with four participants completing the CSA not proceeding with the experiment. The pretest was performed to limit the effect of prior domain knowledge in computer programming on the post-test results. This was achieved by conducting a means analysis on the Qdlv. A further analysis was then conducted on the Qprelv's as an additional check (Table:6C).
<table>
<thead>
<tr>
<th>Cognitive Style Group</th>
<th>Number of Participants</th>
<th>Treatment-1 Mean-Qdlv</th>
<th>Sd</th>
<th>Number of Participants</th>
<th>Treatment-2 Mean Qdlv</th>
<th>Sd</th>
<th>Combined Sd</th>
<th>Treatment-2 minus Treatment-1 Mean-Qdlv</th>
<th>Effect Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wholist</td>
<td>42</td>
<td>-1.009</td>
<td>0.616</td>
<td>38</td>
<td>-0.937</td>
<td>0.606</td>
<td>0.611</td>
<td>0.072</td>
<td>0.117</td>
</tr>
<tr>
<td>Analytic</td>
<td>59</td>
<td>-0.882</td>
<td>0.760</td>
<td>55</td>
<td>-0.975</td>
<td>0.757</td>
<td>0.758</td>
<td>-0.093</td>
<td>0.122</td>
</tr>
<tr>
<td>Verbalizer</td>
<td>41</td>
<td>-1.037</td>
<td>0.769</td>
<td>45</td>
<td>-1.006</td>
<td>0.709</td>
<td>0.740</td>
<td>0.031</td>
<td>0.042</td>
</tr>
<tr>
<td>Imager</td>
<td>60</td>
<td>-0.865</td>
<td>0.652</td>
<td>45</td>
<td>-0.910</td>
<td>0.686</td>
<td>0.669</td>
<td>-0.045</td>
<td>0.067</td>
</tr>
<tr>
<td>Wholist-Verbalizer</td>
<td>19</td>
<td>-1.041</td>
<td>0.714</td>
<td>21</td>
<td>-0.841</td>
<td>0.537</td>
<td>0.632</td>
<td>0.201</td>
<td>0.317</td>
</tr>
<tr>
<td>Analytic-Verbalizer</td>
<td>22</td>
<td>-1.034</td>
<td>0.830</td>
<td>27</td>
<td>-1.134</td>
<td>0.805</td>
<td>0.817</td>
<td>-0.101</td>
<td>0.123</td>
</tr>
<tr>
<td>Wholist-Imager</td>
<td>23</td>
<td>-0.982</td>
<td>0.536</td>
<td>17</td>
<td>-1.057</td>
<td>0.679</td>
<td>0.612</td>
<td>-0.074</td>
<td>0.121</td>
</tr>
<tr>
<td>Analytic-Imager</td>
<td>37</td>
<td>-0.792</td>
<td>0.712</td>
<td>28</td>
<td>-0.821</td>
<td>0.686</td>
<td>0.699</td>
<td>-0.029</td>
<td>0.041</td>
</tr>
</tbody>
</table>
The ES between each SCCS group and ICS sub-group in Treatment-1, and their counterparts in Treatment-2, is small to negligible (Table:6B) with all but one analysis having an ES of < 0.125 (Table:6C). However, the Wholist-Verbalizers with Treatment-2 had a mean-Qlv that was 0.201-logits higher than their Treatment-1 counterparts resulting in an ES of 0.318. This is evidence that these two Wholist-Verbalizer sub-groups differ. This apparent variation in prior domain knowledge will be limited by analysing the Qdlv, rather than just the post-test performance.
4.2 Post-test Performance and Analysis

There were 194-participants that successfully completed the post-test. Of this sample there were 98-males and 96-females. (See sub-section 4.2.4 Interactive effect of instructional treatment and gender). It should be noted that gender analysis was not possible for Pilot-1 and Pilot-2 due to the small sample size. A qualitative review of the post-test responses revealed patterns of more innovative answers from the participants receiving the graphically enhanced treatment (Figure:6.7), than from participants with the text-only format (Figure:6.8). In fact, in the former case, the answers showed liberal use of new metaphors to fully explain the conceptualised programming concepts. Whereas in the latter case, the answers reflected a close resemblance to the expository examples of the text found in the instructional booklet.

Due to the complexity of analysing the QUEST data, the results are presented in the following topics:

- Performance analysis
- Cognitive performance means analysis
- Analysis of the programming-knowledge-performance bands (pkpb)
- Interactive effect of instructional treatment and gender
- Summary
4.2.1 Performance analysis

The histogram (Figure:6.9) of the mean-\(Qdlv\) for each SCCS group (left-half), and each ICS/instructional treatment sub-group (right-half); illustrates the variance in cognitive performance of programming concept acquisition.

The Wholist-Imagers given Treatment-2 were the best performers, with an improvement of 0.312-logits, from the pretest to the post-test. The Analytic-Verbalizers using the same instructional treatment were a distant second with an improvement of 0.235-logits.

However, Analytic-Imagers, also given Treatment-2, were the worst performers; actually scoring lower on the post-test than the pretest by 0.175-logits. The Analytic-Imagers given Treatment-1 also performed poorly, with a mean-\(Qdlv\) of -0.118-logits.
Chapter Six : Results

The box-plots of the groups (Figures 6.10 and 6.11), give a further visual evaluation of the performance variance between instructional treatment groups. Figure 6.10 shows the median and distribution of the SCCS/instructional treatment groups (Wholist, Analytic, Verbalizer, and Imager); whereas Figure 6.11 illustrates the ICS sub-groups (Wholist-Verbalizer, Analytic-Verbalizer, Wholist-Imager, and Analytic-Imager).

Figure 6.10-a shows that although there is variation in the spread of data between groups only the Analytics and Verbalizers given Treatment-1 have a slightly higher QUEST-pretest-median-logit-value than the other groupings. Figure 6.10-b shows, that the Wholist:Treatment-2 group clearly out-performed the other seven groups on the post-test. The median and range of this group are both higher than the other groups.

The Verbalizers:Treatment-2 group also has a slightly higher median and upper distribution limit than the other treatment groups. The outliers at either end of the Analytic:Treatment-2 post-test box plot will partially compensate each other.
The box-plots for the ICS sub-groups (Figures: 6.11-a and 6.11-b) show more variation in test distributions. The Wholist-Verbalizer sub-group, given Treatment-2, has a higher distribution than the other sub-groups for both the pretest and the post-test. However, for the pretest, the median is near the bottom of the Sd-spread; whereas, on the post-test the median is near the top. The Wholist-Imager: Treatment-2 sub-group, has the second highest post-test distribution, with a tight distribution around the high median value. The difference effect for this sub-group is likely to be more than for the Wholist-Verbalizers, because this sub-group’s pretest had a much broader Sd-distribution at lower logit values.

The box-plots also illustrate the poor performance of the Analytic-Imager: Treatment-2 sub-group; moving from one of the top performing sub-groups on the pretest (Figure: 6.11-a) to perhaps the lowest sub-group on the post-test (Figure: 6.11-b).

4.2.2 Cognitive performance means analysis

Both the SCCS groups (Wholist, Analytic, Verbalizer and Imager), and the ICS sub-groups (Wholistic-Verbalizer, Analytic-Verbalizer, Wholistic-Imager and Analytic-Imager) have been analysed for their interactive effect with instructional treatment on cognitive performance.

The three separate analyses that were conducted, will now be discussed:

- **Effect of instructional treatment within the SCCS groups and ICS sub-groups**, (Wholist:Treatment-1 versus Wholist:Treatment-2) (Table: 6D)

- **Cognitive style effect within instructional treatment**, (Wholist:Treatment-1 versus Analytic:Treatment-1) (Table: 6E)

- **Interactive effect of SCCS groups or ICS sub-groups and instructional treatment**, (Wholist:Treatment-1 vs Analytic:Treatment-2) (Table: 6F)
<table>
<thead>
<tr>
<th>Cognitive Style Group</th>
<th>Number of Participants</th>
<th>Treatment-1 Mean-Qdlv</th>
<th>Sd</th>
<th>Number of Participants</th>
<th>Treatment-2 Mean Qdlv</th>
<th>Sd</th>
<th>Combined Sd</th>
<th>Treatment-2 minus Treatment-1 Mean-Qdlv</th>
<th>Effect Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment Means</td>
<td>101</td>
<td>0.002</td>
<td>0.732</td>
<td>93</td>
<td>0.108</td>
<td>0.803</td>
<td>0.768</td>
<td>0.106</td>
<td>0.138</td>
</tr>
<tr>
<td>Wholist</td>
<td>42</td>
<td>0.080</td>
<td>0.580</td>
<td>38</td>
<td>0.225</td>
<td>0.726</td>
<td>0.657</td>
<td>0.146</td>
<td>0.222</td>
</tr>
<tr>
<td>Analytic</td>
<td>59</td>
<td>-0.054</td>
<td>0.824</td>
<td>55</td>
<td>0.026</td>
<td>0.849</td>
<td>0.837</td>
<td>0.080</td>
<td>0.096</td>
</tr>
<tr>
<td>Verbalizer</td>
<td>41</td>
<td>0.063</td>
<td>0.750</td>
<td>48</td>
<td>0.200</td>
<td>0.715</td>
<td>0.733</td>
<td>0.137</td>
<td>0.187</td>
</tr>
<tr>
<td>Imager</td>
<td>60</td>
<td>-0.040</td>
<td>0.723</td>
<td>45</td>
<td>0.009</td>
<td>0.884</td>
<td>0.808</td>
<td>0.049</td>
<td>0.061</td>
</tr>
<tr>
<td>Wholist-Verbalizer</td>
<td>19</td>
<td>0.073</td>
<td>0.533</td>
<td>21</td>
<td>0.155</td>
<td>0.721</td>
<td>0.634</td>
<td>0.082</td>
<td>0.130</td>
</tr>
<tr>
<td>Analytic-Verbalizer</td>
<td>22</td>
<td>0.055</td>
<td>0.910</td>
<td>27</td>
<td>0.235</td>
<td>0.723</td>
<td>0.822</td>
<td>0.181</td>
<td>0.220</td>
</tr>
<tr>
<td>Wholist-Imager</td>
<td>23</td>
<td>0.085</td>
<td>0.628</td>
<td>17</td>
<td>0.312</td>
<td>0.745</td>
<td>0.689</td>
<td>0.227</td>
<td>0.329</td>
</tr>
<tr>
<td>Analytic-Imager</td>
<td>37</td>
<td>-0.118</td>
<td>0.774</td>
<td>28</td>
<td>-0.175</td>
<td>0.923</td>
<td>0.852</td>
<td>-0.057</td>
<td>0.066</td>
</tr>
</tbody>
</table>
4.2.2 (a) Effect of instructional treatment within the SCCS groups & ICS sub-groups

The first-means-analysis should determine whether any of the SCCS groups performed better with one instructional treatment, or the other.

The null hypothesis being tested is:

\[ H_2: \text{Cognitive performance will not be affected by the type of instructional treatment received.} \]

Or, in other words the Wholist group given Treatment-1, should have the same difference-mean-QdLv, as the Wholist group given Treatment-2.

The data, summarised in Table:6.D, indicates that instructional treatment does have a small to medium effect on cognitive performance. On the entire population, with no cognitive style interaction, the ES between instructional treatments is 0.138, which indicates an approximate 35% chance of rejecting the null hypothesis (Cohen,1977:31).

The Wholist group (ES=0.222), and Wholist-Imager sub-group (ES=0.329), have a 40 to 45% chance of rejecting the null hypothesis. As can be seen from the mean-QdLv column, both of these cognitive-style-groupings performed better with Treatment-2, the text-plus-graphical metaphor instructional format.

Although there is a negligible ES, it is interesting to note that both Analytic-Imager sub-groups achieved negative mean-QdLv's, performing worse on the post-test than the pretest relative to the other participants. This result was expected to have an effect on the subsequent analysis, where this ICS sub-group is compared with other ICS sub-groups.
<table>
<thead>
<tr>
<th>Cognitive Style Treatment Group</th>
<th>Number of Participants</th>
<th>Mean-Qdlv</th>
<th>Sd</th>
<th>Cognitive Style Treatment Group</th>
<th>Number of Participants</th>
<th>Mean-Qdlv</th>
<th>Sd</th>
<th>Combined Sd</th>
<th>Mean-Qdlv Difference</th>
<th>ES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wholists : T1</td>
<td>42</td>
<td>0.080</td>
<td>0.580</td>
<td>Analytics : T1</td>
<td>59</td>
<td>-0.054</td>
<td>0.824</td>
<td>0.712</td>
<td>-0.133</td>
<td>0.187</td>
</tr>
<tr>
<td>Wholists : T2</td>
<td>38</td>
<td>0.225</td>
<td>0.726</td>
<td>Analytics : T2</td>
<td>55</td>
<td>0.026</td>
<td>0.849</td>
<td>0.790</td>
<td>-0.199</td>
<td>0.251</td>
</tr>
<tr>
<td>Verbalizers : T1</td>
<td>41</td>
<td>0.063</td>
<td>0.750</td>
<td>Imagers : T1</td>
<td>60</td>
<td>-0.040</td>
<td>0.723</td>
<td>0.737</td>
<td>-0.103</td>
<td>0.140</td>
</tr>
<tr>
<td>Verbalizers : T2</td>
<td>48</td>
<td>0.200</td>
<td>0.715</td>
<td>Imagers : T2</td>
<td>45</td>
<td>0.009</td>
<td>0.884</td>
<td>0.804</td>
<td>-0.191</td>
<td>0.238</td>
</tr>
<tr>
<td>Whol-Verb : T1</td>
<td>19</td>
<td>0.073</td>
<td>0.533</td>
<td>Ana-Verb : T1</td>
<td>22</td>
<td>0.055</td>
<td>0.910</td>
<td>0.746</td>
<td>-0.018</td>
<td>0.024</td>
</tr>
<tr>
<td>Whol-Verb : T1</td>
<td>19</td>
<td>0.073</td>
<td>0.533</td>
<td>Whol-Imag : T1</td>
<td>23</td>
<td>0.085</td>
<td>0.628</td>
<td>0.582</td>
<td>0.013</td>
<td>0.022</td>
</tr>
<tr>
<td>Whol-Verb : T1</td>
<td>19</td>
<td>0.073</td>
<td>0.533</td>
<td>Ana-Imag : T1</td>
<td>37</td>
<td>-0.118</td>
<td>0.774</td>
<td>0.664</td>
<td>-0.191</td>
<td>0.288</td>
</tr>
<tr>
<td>Whol-Imag : T1</td>
<td>23</td>
<td>0.085</td>
<td>0.628</td>
<td>Ana-Imag : T1</td>
<td>37</td>
<td>-0.118</td>
<td>0.774</td>
<td>0.705</td>
<td>-0.204</td>
<td>0.289</td>
</tr>
<tr>
<td>Whol-Imag : T1</td>
<td>23</td>
<td>0.085</td>
<td>0.628</td>
<td>Ana-Verb : T1</td>
<td>22</td>
<td>0.055</td>
<td>0.910</td>
<td>0.782</td>
<td>-0.031</td>
<td>0.039</td>
</tr>
<tr>
<td>Ana-Verb : T1</td>
<td>22</td>
<td>0.055</td>
<td>0.910</td>
<td>Ana-Imag : T1</td>
<td>37</td>
<td>-0.118</td>
<td>0.774</td>
<td>0.845</td>
<td>-0.173</td>
<td>0.205</td>
</tr>
<tr>
<td>Whol-Verb : T2</td>
<td>21</td>
<td>0.155</td>
<td>0.721</td>
<td>Ana-Verb : T2</td>
<td>27</td>
<td>0.235</td>
<td>0.723</td>
<td>0.722</td>
<td>0.080</td>
<td>0.111</td>
</tr>
<tr>
<td>Whol-Verb : T2</td>
<td>21</td>
<td>0.155</td>
<td>0.721</td>
<td>Whol-Imag : T2</td>
<td>17</td>
<td>0.312</td>
<td>0.745</td>
<td>0.733</td>
<td>0.157</td>
<td>0.214</td>
</tr>
<tr>
<td>Whol-Verb : T2</td>
<td>21</td>
<td>0.155</td>
<td>0.721</td>
<td>Ana-Imag : T2</td>
<td>28</td>
<td>-0.175</td>
<td>0.923</td>
<td>0.828</td>
<td>-0.330</td>
<td>0.398</td>
</tr>
<tr>
<td>Whol-Imag : T2</td>
<td>17</td>
<td>0.312</td>
<td>0.745</td>
<td>Ana-Imag : T2</td>
<td>28</td>
<td>-0.175</td>
<td>0.923</td>
<td>0.839</td>
<td>-0.487</td>
<td>0.580</td>
</tr>
<tr>
<td>Whol-Imag : T2</td>
<td>17</td>
<td>0.312</td>
<td>0.745</td>
<td>Ana-Verb : T2</td>
<td>27</td>
<td>0.235</td>
<td>0.723</td>
<td>0.734</td>
<td>-0.077</td>
<td>0.104</td>
</tr>
<tr>
<td>Ana-Verb : T2</td>
<td>27</td>
<td>0.235</td>
<td>0.723</td>
<td>Ana-Imag : T2</td>
<td>28</td>
<td>-0.175</td>
<td>0.923</td>
<td>0.829</td>
<td>-0.410</td>
<td>0.495</td>
</tr>
</tbody>
</table>

T1 = Treatment 1 (Text plus Textal Metaphor)  
T2 = Treatment 2 (Text plus Graphical Metaphor)
4.2.2 (b) Cognitive style effect within instructional treatment

The second-means-analysis should determine whether any of the SCCS groups or ICS sub-groups performed better than other cognitive style groups/sub-groups, using the same instructional treatment.

The null hypothesis being tested is:

\[ H_3 \text{ Cognitive performance will not be affected by the individual's cognitive style.} \]

Or, in other words, the Wholist group given Treatment-1, should have the same difference-mean-Qdlv, as the Analytic group given Treatment-1.

This means analysis, Table:6E, indicates that cognitive style also has a small to medium effect on cognitive performance, with one large-effect pairing. As expected, the largest effect is present in comparisons including the Analytic-Imagers, with one ICS sub-group having a large-ES, and two others approaching this category. The Wholist-Imagers sub-group using Treatment-2, which had the highest mean-Qdlv (0.312) of the experiment, has an ES of 0.580, when compared to the Analytic-Imagers using the same instructional treatment.

With a sample-size of 45-participants and using an \( \alpha \) of 10\%, this analysis has a statistical-power of 85\% (Cohen,1977:30). There is a strong possibility that cognitive style did affect cognitive performance. Similarly, a statistical-power of over 80\% is obtained from a comparison of Analytic-Verbalizers with the Analytic-Imagers given Treatment-2, and a statistical-power of over 60\% is calculated for the Wholistic-Verbalizers to Analytic-Imagers:Treatment-2 comparison.

Furthermore, a statistical-power of over 50\%, is obtained for the Wholist to Analytic:Treatment-2 analysis (ES=0.252), and Verbalizers to Imagers:Treatment-2 analysis (ES=0.238).
<table>
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<th>Cognitive Style Treatment Group</th>
<th>Number of Participants</th>
<th>Mean-Qdlv</th>
<th>Sd</th>
<th>Cognitive Style Treatment Group</th>
<th>Number of Participants</th>
<th>Mean-Qdlv</th>
<th>Sd</th>
<th>Combined Sd</th>
<th>Mean-Qdlv Difference</th>
<th>ES</th>
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T1 = Treatment 1 (Text plus Textal Metaphor)  
T2 = Treatment 2 (Text plus Graphical Metaphor)
4.2.2 (c) Interactive effect of SCCS groups or ICS sub-groups and instructional treatment

The third-means-analysis should determine whether there is an interactive effect of cognitive style with instructional treatment.

The null hypothesis being tested is:

\[ H_4: \text{Cognitive performance will not be affected by the interaction of cognitive style with the type of instructional treatment.} \]

Or, in other words, the Wholist group given Treatment-1, should have the same mean-Qdlv as the Analytic group given Treatment-2.

The interactive effect of cognitive style and instructional treatment is larger than in the previous two analyses, with nine of the 16-comparisons in the medium to large effect category (Table:6F).

The largest effect (ES=0.566) is between Wholist-Imagers:Treatment-2 and Analytic-Imagers:Treatment-1. This results in a statistical-power of over 85% (given the sample-size of 54-participants and \( a_2 \) of 10%).

The statistical-power is over 75% for three other comparisons (Cohen,1977:30&31):

- Analytic-Verbalizers:Treatment-2 versus Analytic-Imagers:Treatment-1 (ES=0.472)
- Wholists-Treatment-2 versus Analytics:Treatment-1 (ES=0.359) and
- Verbalizers-Treatment-2 versus Imagers:Treatment-1 (ES=0.334)

In these four analyses there is evidence to reject the null hypothesis, therefore:

There is most likely an interactive effect of cognitive style and type of instructional treatment on cognitive performance.

Furthermore, the remaining five medium ES analyses, have statistical-power probabilities of 40 - 65%, where the null hypothesis could also be rejected.

4.2.3 Analysis of the programming-knowledge-performance bands (pkpb)

So far, the data analysis has concentrated on the participants' Qlv's. However, the Qls not only measures the participants' cognitive performance, relative to each other, but their performance relative to the test-items as well. Figures:6.12 and 6.13, illustrate the participants and test-items relative positions on the pretest and post-test common-Qls.
Figure: 6.12 QUEST Variable Map: Pretest

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Each X represents 1 participant.

The decimal point denotes partial credit score level (MIO). See Appendix.
Figure:6.13 QUEST Variable Map : Post-test

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The decimal point denotes partial credit score level (MIO). See Table:6G

Each LETTER represents 1 participant

Legend

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<th>Treatment-2</th>
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<td>D = Analytic:Imager</td>
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## Chapter Six: Results

Figure: 6.14 QUEST Test-Item Fit Map

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The QUEST Item Fit Map (Figure: 6.14) provides a visual check of magnitude of the fit statistic for the test-items. Overall, these test-items fit the Rasch model, with the exception of test-item-34, which fall outside of the left-hand vertical dotted line, indicating a mean square that is 30% below its expected value. See Appendix for the QUEST Item Analysis Results for both a traditional and Rasch statistics summary for each test-item.

Each test-item has been designed to test for specific types of knowledge (see Chapter Five: Research Methodology and Experimental Design, sub-section, 2.6 Measurable Instructional Outcomes). In general, the higher the programming-knowledge required to correctly answer a question, the higher on the common-Qls the test-item will appear; ranging from pkpb-1 (-3.0 to -2.5 logits) to pkpb-12 (3.0 to 3.5 logits) (Table:6G). The measurable instructional outcomes (MIO’s), shown on the right side in Table:6G, provides a pkpb framework (measured against the -3.5 to 3.0 common-Qls), to reflect the relationship between cognitive performance and test-item behaviour.
It is therefore possible to identify four levels of programming skill using the common-Qls in this manner.

The programming skills for the post-test are shown in Table:6G as:

1. **verbal information**  
   2. **intellectual skill**  
   3. **cognitive strategy**: applies isolated concepts and principles (pkpb-4)  
   4. **cognitive strategy**: demonstrates programming concept (pkpb-6 - pkpb-12)

The associated programming knowledge bands were identified as:

1. **declarative knowledge**: rule only (pkpb-3)  
2. **declarative knowledge**: higher-order-rules (pkpb-4)  
3. **identifying sub-tasks** (pkpb-5)  
4. **procedural knowledge**: demonstration of the how (pkpb-6 to pkpb-12)
Chapter Six : Results

The categories of demonstrated *programming knowledge* abilities were:

1. discriminating programming concept
2. applying concept to new programming situation
3. able to apply sub-tasks
4. demonstrate correct programming solution involving unstated assumptions.

Analysis of the *pkpb distribution* has been conducted, focussed in two ways (*participant* and *test-item*).

4.2.3 (a) Participant performance

The *first-pkpb-analysis* quantifies the movement of participants from *pretest* to *post-test* between the *pkpb's* (Figure:6.15). The histograms display the number of participants in the *pkpb* on the *post-test*, relative to the number of that group in the same *pkpb* in the *pretest* (see Appendix for *pretest* and *post-test pkpb distribution*). For instance: the *Wholist:Treatment-1 group* had 13-members in *pkpb-5* on the *pretest*, and 17-members in *pkpb-5* on the *post-test*. Figure:6.15-a, shows a *plus-4-movement*. This analysis is a qualitative evaluation of whether the group improved in *programming knowledge/skill level*.

The total population has been divided as before, first along the *SCCS groups* (*Wholist, Analytic, Verbalizer, Imager*) (Figure:6.15-a), and then on the *ICS sub-groups* (*Wholist-Verbalizer, Analytic-Verbalizer, Wholist-Imager, and Analytic-Imager*) (Figure:6.15-b). These results will be discussed below.

The *pkpb analysis* generally reinforces the observations from the *means analysis*, with the high performing groups having a positive movement into the upper performance levels (*pkpb-8 to pkpb-6*), from the *pretest* to *post-test*, and the low performance groups shifting to the lower *pkpb’s*.

4.2.3 (a) (i) Single-category-of-cognitive-style (SCCS) groups

The *Wholist:Treatment-2 group* has an additional five *participants* in the top three *pkpb's* (*pkpb-8 to pkpb-6*) than the group had in the *pretest* results (Figure:6.15-a).

This result represents a shift of 13% of the *Wholist:Treatment-2 group* into the upper three performance levels. Furthermore, the shift in performance is from the lower-levels, *pkpb-3* and *pkpb-2*, and not from the average performance levels of *pkpb-5* and *pkpb-4*.

The *Verbalizers:Treatment-2 group*, had a net gain in the upper *pkpb-8 to pkpb-6*, of *nine participants*, or almost 20% of the *Verbalizers*, given the *graphical metaphor instructional treatment*. 
Figure: 6.15-a  Relative Movement Between pkpb's From Pre to Post-Test (SCCS Groups)

Figure: 6.15-b  Relative Movement Between pkpb's From Pre to Post-Test (ICS Sub-groups)
Much of this gain has come from pkpb-5, and therefore the means analysis did not show as much improvement as the Wholist:Treatment-2 group.

The Analytic:Treatment-1 group has a net loss of seven participants (-12%), from the upper performance levels, which was reflected in the means analysis by a negative post-test minus pretest mean-Qdlv.

The remaining SCCS groups show small gains or losses, which are inconclusive.

4.2.3 (a) (ii) Integrated-cognitive-style (ICS) sub-groups

Figure:6.15-b shows a similar analysis for the ICS sub-groups (Wholist-Verbalizer, Analytic-Verbalizer, Wholist-Imager, and Analytic-Imager).

The Wholist-Verbalizer:Treatment-2 performance level analysis (Figure:6.15-b), shows a net gain to the upper pkpb's of 5-participants, or 24% of that sub-group. This is the largest gain of the ICS sub-group analysis.

The majority of this improvement has come from the average pkpb-5 and pkpb-4 levels, with little improvement of the lower pkpb's, and therefore, this sub-group only rated third top performance on the means analysis (Figure:6.9).

Analytic-Verbalizers:Treatment-2, show a net gain of four participants to the upper pkpb's. This represents approximately 15% of this sub-group.

Besides the improvement to the upper pkpb's, there is limited upward movement in the lower levels. The pkpb analysis does not adequately reveal this sub-group's improvement observed in the means analysis. (See Tables:6E and 6F).

Therefore, performance improvements must be more subtle movements within the pkpb's, with a general shift of Analytic-Verbalizers:Treatment-2 participants from the lower portion of each knowledge band to the upper portion of the same pkpb.

The participant pkpb analysis for Analytic-Imagers:Treatment-1 shows a net loss of four participants from the upper pkpb's, representing a decrease in performance of approx.11% of the sub-group.

Given this sub-group's poor results in the means analysis (Figure:6.9), it is not surprising that they did not answer the higher-skilled test-items on the post-test.

However, the Analytic-Imagers:Treatment-2, who had a lower means difference score than their counterparts with the textual metaphor instructional treatment (Figure:6.9), only had a net loss of one participant from the upper pkpb's.
There is, however, a general downward shift, from one \textit{pkpb} level to the next, throughout the \textit{common-Qls}.

The other anomalous result is the \textit{Wholist-Imagers:Treatment-2} sub-group, who showed the largest means difference improvement (Figure:6.9). There is no net movement to/from the upper \textit{pkpb}'s (Figure:6.15-b). There is, however, a shift of four participants (approx.24\% of the sub-group), from the \textit{pkpb-3} and \textit{pkpb-2} levels, to \textit{pkpb-5}.

There is an expectation, nevertheless, that within each \textit{treatment group} there will be variation during the conduct of each experiment in individual \textit{cognitive performance}. Fluctuations will occur, and therefore analysis of an individual's performance may not reflect the patterns identified in the \textit{means analysis} of the treatment groups. Consequently, large differences may be regarded as a problem of statistical fit (Izard,1995).

Figure:6.16 locates the \textit{cognitive performance} fit statistic for four participants. (See Appendix for the full \textit{QUEST Participant Estimate Table}). In this example, the two \textit{Wholist-Imagers} fit the Rasch model (shown as asterisks lying between the two vertical dotted lines), while the two \textit{Analytic-Imagers} do not.

The statistical fit of 2.07 for participant 0106MAI, indicates a random and erratic performance! The \textit{finer-grained} analysis of his \textit{QUEST Kid Map} (Figure:6.17) reveals this participant, on the one hand, successfully completed some of the more difficult test-items requiring \textit{procedural knowledge} (see Table:6G) on the pretest (test-items-9, 15, 19 and 20),
and test-items 38 and 39 on the post-test (refer to the top left quadrant of (Figure:6.17), while not achieving some of the straightforward skill level (SF), post-test test-items which draw on the intellectual skills or declarative knowledge (test-items 28, 31, 32, 34, 36, 37 and 40). Refer to the bottom right quadrant.

Furthermore, inspection of these easier test-items not achieved reveals the inconsistency of his performance, whereby the programming knowledge skill category of verbal information (knowing the rule only) was not demonstrated. Yet he was able to successfully complete some of the programming tasks in the pretest which required a cognitive strategy to know basic terms and identify sub-tasks.
The statistical fit of .41 for participant 0308MAI (Figure:6.18), is also not considered by the QUEST estimate to fit the model. However, unlike the previous example (0106MAI Figure:6.17), this performance is extremely predictive. For instance, note the relationship between the number of easier achieved test-items falling in the bottom left quadrant, and the harder achieved (top right quadrant). There are just two test-items of those completed, which the QUEST estimate considers as difficult for this participant (pretest test-item-6 and post-test test-item-20.1). Furthermore, he missed only four test-items, with MIO level-2, requiring a SF response (Table:6G).
In the example above, the statistical fit of 1.21 for participant 0901FWI (Figure:6.19) fits the Rasch model. Test-item-39.4 denotes the example answer given in Figure:6.8. Note that the majority of test-items lie either below the ability estimate (the XXX) in the bottom left quadrant, or above in the upper right corner. Interestingly, despite having the textual metaphor instructional treatment, all the test-items (with the exception of test-item-33) deemed by the QUEST estimate as easier not achieved, involve verbal information. The five post-test test-items not achieved, are the five lowest MIO's (Table:6G).
Final Experiment

Figure 6.20 Predictable Performance Treatment-2

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                                    K    I    D    M    A    P
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Participant: 1202MWI               ability:  -0.82
group: all (Text-plus-graphical metaphor treatment)  fit: 1.33
scale: all                         % score: 34.25

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The statistical fit of 1.33 for participant 1202MWI (Figure 6.20) also fits the Rasch model. Once more, test-item-39.4 denotes the example answer given in Figure 6.7. Consequently, comparing these two participants (0901FWI given the text-plus-textual metaphor format, and 1202MWI the text-plus-graphical metaphors) provides an opportunity to directly observe how a participant with the same cognitive style has performed.

It would appear that the participant 0901FWI was not able to succeed in answering the more difficult test-items on the post-test. Whereas participant 1202MWI has been successful in completing more of the harder programming test-items on the post-test.
Table 6.1: Comparison of Test-Items Between ICS Sub-Groups

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4.2.3 (b) Test-item performance: Measurable instructional outcomes

The second-pkp-analysis evaluates how each instructional treatment group performed on specific test-items, by conducting separate QUEST analyses for each instructional treatment group, and listing the pkpb where each test-item is rated.

A comparison between instructional treatment groups will show whether participants with certain categories-of-cognitive-style have difficulty answering one
type of test-item, relative to another. For instance, do Wholist-Verbalizers have difficulty answering questions, which require declarative knowledge, if they are only given textual instructional treatments?

Comparison of test-item difficulty for each ICS treatment sub-group has been conducted. In Table:6H test-item numbers range from 20:00 to 40:04, with the scoring method depicted as: dichotomous (00 wrong, 01 correct); or partial credit (00 wrong; 01, 02, 03, 04) levels of MIO (Table:6G). The second column in Table:6H, illustrates the pkpb-levels and the exact position of the test-item on the common-Qls. The position of each MIO on the common-Qls is used to measure performance probabilities of the test-item for each ICS sub-group. For instance, the performance of test-item 40:02 achieved a pkpb-level of 4:06 on the common-Qls, whereas the Wholist-Verbalizer:Treatment-2 sub-group, achieved a 4:07 pkpb. Their counterparts with Treatment-1 answered this test-item at pkpb-level 5:03.

In Table:6H, each ICS sub-group has been compared with their counterparts using the other instructional treatment. The yellow-boxes indicate that this sub-group answered this test-item at one pkpb-sub-level higher than their counterparts with the opposite treatment. Since the higher pkpb's have a larger Qlv, it means that the highlighted treatment sub-group had a lower probability of answering the specific post-test test-item. However, one pkpb-sub-level may not be a significant variation!

On the other hand, the black and green-boxes indicate a pkpb variation of two-or-more sub-levels, with many showing a full pkpb variation (5:09 to 4:09).

The black boxes show where a sub-group has performed much worse (higher pkpb sub-level). The majority of these cases occur on the final test-item of the post-test (test-items 40:01, 40:02, 40:03 and 40:04). This implies a lack of time, or fatigue may have had a negative impact on the participants' ability to correctly answer this test-item. However, it is notable that only some of the treatment sub-groups were adversely affected (Wholist-Verbalizer:Treatment-1, Analytic-Verbalizer:Treatment-2 and Wholist-Imager:Treatment-1).

The green-boxes indicate where a treatment sub-group has performed significantly better than the general population. For instance: Wholist-Imagers:Treatment-2 clearly out-performed the other sub-groups on test-item:34 (a pkpb sub-level of 5:07, compared to 7:07/7:08; for the other sub-groups on 34:04; and 4:09, compared to 5:07 on 34.03).

The results for the test-items within ICS sub-groups (Wholist-Verbalizer, Analytic-Verbalizer, Wholist-Imager, Analytic-Imager) follow:
4.2.3 (b) (i) Wholist-Verbalizers

The Wholist-Verbalizers given Treatment-1 have performed better than their Treatment-2 counterparts, on the higher-pkpb's for programming skills (pkpb-12 to pkpb-7), and the Intellectual and Verbal Information Skills (pkpb-4 and pkpb-3 respectively). However, except for test-item 35:04 (6:02 compared to 7:02), and pkpb-3 test-items, they have performed worse on several test-items in the upper-level of the Intellectual Skills (upper pkpb-4) and through the lower portion of the Cognitive Strategy (pkpb-5). On the majority of these test-items, the Treatment-1 sub-group has performed two-or-more pkpb sub-levels worse than their counterparts (black boxes on Table:6H).

Overall, this analysis of test-item pkpb sub-levels is inconclusive as to which instructional treatment the Wholist-Verbalizers perform best with (the ES, Table:6D, was negligible).

4.2.3 (b) (ii) Analytic-Verbalizers

The Analytic-Verbalizers' test-item analysis shows no variation between the subgroups, except for test-items 29, 30 and 40. The Treatment-2 sub-group did not perform well on test-item 40, showing poorer performance at all levels of that test-item (black boxes on Table:6H). However, the Treatment-1 sub-group, did not score at all on test-items 29 and 30 (green-boxes on Table:6H).

Although the Treatment-2 sub-group performed badly on test-item 40 (possibly due to time constraints), the high performance on test-items 29 and 30 gives this sub-group a qualitative edge, compared to their Treatment-1 counterparts.

4.2.3 (b) (iii) Wholist-Imagers

The Treatment-2 sub-group performed one-pkpb sub-level worse than their Treatment-1 counterparts (yellow-boxes on Table:6H) throughout much of the Declarative Knowledge Band (pkpb-4 and pkpb-3). However, they outperformed their Treatment-1 counterparts, on test-items 30, 34 (green-boxes), and test-item 40 (black boxes).

Due to their better performance on the higher skill level test-items, Wholist-Imagers, are likely to perform better with Treatment-2. However, they may have difficulty with the Declarative Knowledge Skills.

4.2.3 (b) (iv) Analytic-Imagers

The Treatment-1 sub-group has performed one-pkpb sub-level worse, than their counterparts on several of the upper-skill-level test-items (pkpb-10 to pkpb-7).
However, the Treatment-2 sub-group did not score on test-item 30:03, and performed at a lower level, than their Treatment-1 counterparts through the remaining lower-skill-levels (pkpb-6 to pkpb-3).

The test-item analysis is inconclusive for the Analytic-Imagers. However, the Treatment-1 sub-group may have an advantage over a majority of the MIOs.

4.2.4 Interactive effect of instructional treatment and gender

There was a total of 98-males and 96-females in the final experiment. Of the males, 45- were given the textual metaphors, and 53- the graphical metaphors; whereas 56-females were given the former instructional treatment, and the remainder (40) graphical metaphors.

Figure:6.21 shows the relative distribution of these four-groups, with females given the graphical metaphors achieving the highest post-test distribution, and females with textual format having the lowest distribution. The two male groupings have similar distributions, resting between the two female distributions.

The interactive ES of gender, with the experiment's variables, is shown In Table:6I.

The null hypothesis being tested is:

\[ H_5 \text{ Gender will have no affect on the cognitive performance of one treatment group (instructional strategy/cognitive style) compared to another.} \]
For instance: a female-Verbalizer, given the textual metaphor instructional treatment, will perform at the same level as a male-Imager given the same treatment.

As displayed in the previous box-plots (Figure:6.21), the top line of Table:6I shows that gender had a negligible effect on performance, with an overall ES of only 0.050. Females with the graphical-metaphor treatment were the best performers (mean Qdlv=0.134), whereas the females with the textual treatment, had the lowest mean Qdlv at -0.040.

The second segment in Table:6I indicates that there was a negligible interactive effect of gender and instructional treatment on cognitive performance. The highest ES is only 0.164 (males with graphical treatment compared to females with textual treatment), which gives a statistical power of less than 30% (Cohen,1977:31).

Due to the population size, the interactive effect of Riding's two cognitive style continua (the ICS sub-groups) cannot be analyzed. However, the interactive effect of gender and the SCCS groups can be investigated.

4.2.4 (a) Gender and Wholist-Analytic dimension

The interactive effect on cognitive performance of gender and the Wholist-Analytic dimension is also small to negligible (Table:6I, upper segment-3). The highest ES is 0.225 (male-Analytics versus female-Analytics, both with the textual treatment), giving a 34% chance of rejecting the null hypothesis (Cohen,1977:31).

As with the previous means analysis (sub-topic 4.2.2 (c) Interactive effect of SCCS groups or ICS sub-groups and instructional format), the interaction of cognitive style and instructional treatment increases the ES. Half of the analysis (lower portion of segment-3, Table:6I) has an ES of over 0.2, with one medium ES. The male-Wholists, with the graphical metaphor format compared to the female-Analytics with the textual metaphors (ES = 0.472), indicates an 80% chance (Cohen,1977:31), that the interaction of gender, cognitive style (Wholist-Analytic) and instructional treatment, had an affect on cognitive performance. However, Table:6F shows a similar statistical power (~79%, ES = 0.359), when comparing Wholists given the graphical metaphors, with Analytics using the textual metaphors, regardless of gender.
Table: Interactive Size Effect of Gender on Experimental Variables

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T1 = Treatment 1 (Text plus Textual Metaphor)  
T2 = Treatment 2 (Text plus Graphical Metaphor)
The performance level analysis shows that male-Wholists, using the graphical metaphor treatment, have shown the best improvement with a net gain of four participants (17%) into the upper pkpb’s. Conversely the male-Analytics, with the textual metaphors, have shown the worst performance with a net loss of four participants (15%), from the upper pkpb’s (Figure:6.22).

The best-performing female group is the Analytics with graphical metaphors, shifting 2-participants (8%) into the higher pkpb’s, while their counterparts, Analytics with the textual metaphor treatment, are the worst performing female group, losing three-participants (10%) from the upper pkpb’s (Figure:6.22).

4.2.4 (b) Gender and Verbalizer-Imager dimension

Means analysis of the interactive effect of gender and the Verbalizer-Imager dimension on cognitive performance shows similar results to the Wholist-Analytic analysis. There is very limited effect with the highest ES only 0.187 (upper portion of segment-4, Table:6I), a statistical power of less than 20% (Cohen,1977:30).

The interaction of gender, the Verbalizer-Imager dimension and instructional treatment, has an increased effect on cognitive performance, with half of the analysis having an ES of over 0.2. There are two analyses with a medium ES, male-Verbalizers/graphical metaphor treatment versus female-Imagers/textual metaphor treatment (ES = 0.310); and female-Verbalizers/graphical metaphors versus male-Imagers/textual metaphors (ES = 0.349). The chance of rejecting the null
hypothesis is 50 to 55% (Cohen,1977:31). However, the statistical power of all Verbalizers with the graphical metaphors compared to all Imagers with the textual metaphors was over 75% (ES = 0.334, Table:6F).

The performance level analysis, Figure: 6.22, shows the male-Verbalizers with graphical metaphors are the best performing group with five-members (21%), moving into the upper pkpb's. Female-Verbalizers with the same instructional treatment (Figure:6.22) also performed well, with four participants (17%) moving up to the upper pkpb's. All of the other groups had no change or a decline in upper pkpb members.

In summary:

There appears to be no major effect of gender on performance levels. The means analysis (Table:61) indicates that ES is predominantly small to negligible. There are three analyses showing medium interactive effect of gender, the SCCS groups and instructional treatment. However, the ES is equivalent or smaller than the same comparison of SCCS treatment groups, without the gender variable.

The performance level analysis reinforces the above finding. Although there is variation in the amount of performance improvement or decline, the male and female sub-groups appear to behave in the same manner. For instance, the male-Verbalizers with the graphical metaphor treatment had a shift of five-members into the upper pkpb's, while the equivalent female group had a positive shift of four-members. Conversely, the male-Analytics with the graphical metaphors had a performance decline of four-members, from the upper pkpb's, while their female counterparts lost three members, to the lower performance levels.
5. Evaluation of Results

In order to focus the following chapter (meta-knowledge acquisition process), a brief summary of the final experiment's results is necessary. This will be structured by a description of the performance of the SCCS groups and ICS sub-groups, noting the conclusion on which instructional format (text-plus-textual or text-plus-graphical metaphors), each group and sub-group performed best with, and the data used to reach this conclusion.

5.1 SCCS groups

The SCCS group consist of the two Riding & Cheema (1991) cognitive style continua (Verbal-Imagery; Wholist-Analytic), split into halves, firstly into Wholists and Analytics, and then into Verbalizers and Imagers.

5.1.1 Wholists

The Wholists clearly performed better with the text-plus-graphical metaphors, than with the text-plus-textual metaphors. Their textual metaphor group Qdlv of 0.225, is the highest logit value of all the SCCS groups (Figure:6.9), and is 0.146 logits higher than their textual metaphor treatment counterparts. This results in an ES of 0.222 (Table:6D), and a 40% probability, that the instructional treatment affected performance. The box plots (Figure:6.10-a and -b) show that the Wholist:Graphical metaphor group had a higher median and spread, than their textual metaphor treatment counterparts. The pkpb participant performance analysis (Figure:6.15-a) also shows the graphical metaphor treatment group performing better than their textual metaphor treatment counterparts, with five-participants (13%) moving into the upper pkpb levels (6 to 8) on the post-test, compared to no gain, for the textual metaphor treatment group.

5.1.2 Analytics

Analytics also performed best, with the graphical metaphor instructional treatment, with a 0.803 logit higher mean Qdlv, than the text-plus-textual metaphor treatment group. The latter group actually performed worse on the post-test than the pretest, relative to the other groupings, with a Qdlv of -0.054 (Figure:6.9 and Table:6D). However, the ES (0.096) is negligible (Table:6D), indicating that treatment type had little effect on the Analytics' performance. The post-test box plot (Figure:6.10-b) confirms this conclusion, with little variation in median or spread between the text-plus-textual metaphor treatment and Analytic:Text-plus-graphical metaphor treatment groups. On the other hand, the participant focussed pkpb analysis amplifies the graphical metaphors groups' small advantage seen in the statistical analysis. Although the text-plus-graphical metaphor treatment group has a modest +3 (5.45%) shift to the upper pkpb levels (6 to

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(Continued on the next page)
8), the text-plus-textual metaphor treatment group has a seven participant (approx.12%) negative shift from these upper levels to lower programming performance bands (Figure:6.15-a).

5.1.3 Verbalizers
Figures:6.9 and 6.10-b indicate that Verbalizers perform better with text-plus-graphical metaphor treatment, than with the text-plus-textual metaphors. The Verbalizer:Text-plus-graphical treatment mean Qdlv is 0.137 higher (Table:6D), and their post-test median and spread are higher than their textual metaphor treatment counterparts. Although the ES (0.187) is small (Table:6D), the pkpb analysis (Figure:6.15-a) shows a large advantage to the graphical metaphor treatment group. Nine participants (approx.20%) of the graphical metaphor treatment group has moved into the upper pkpb levels on the post-test. This compares to a negative shift of three participants, in the text-plus-textual treatment group.

5.1.4 Imagers
The Imager:Text-plus-graphical metaphor treatment group has performed slightly better than their textual metaphor treatment counterparts, with a higher mean Qdlv of 0.009 compared to -0.040 (Table:6D). The ES of 0.061 is negligible. Neither Imager group has performed well relative to the other SCCS groups. The box plots (Figure:6.10-b) show similar medians, with the graphical metaphor treatment group having a slightly higher upper spread limit than the textual metaphor treatment group. The participant focussed pkpb analysis confirms that both groups have performed relatively poorly, and that the graphical metaphor treatment group has performed marginally better than their textual metaphor treatment counterparts. The text-plus-graphical metaphor treatment group had a negative shift of one participant (approx.2%), from the upper pkpb’s (6 to 8), whereas the text-plus-textual metaphor treatment group lost four participants (approx.6.7%) from the post-test pkpb upper levels (Figure:6.25-a).

5.2 ICS Sub-Groups
The ICS sub-groups integrate the two Riding & Cheema (1991) cognitive style continua, splitting the sample into four sub-groups (Wholist-Verbalizer, Analytic-Verbalizer, Wholist-Imager, and Analytic-Imager).

5.2.1 Wholist-Verbalizer
The Wholist-Verbalizer:Text-plus-graphical metaphor treatment sub-group obtained a higher mean-Qdlv (0.155) than their text-plus-textual metaphor treatment counterparts (0.073) (Figure:6.9). The resulting ES of 0.130 (Table:6D) is small to negligible. The box plots (Figures:6.11-a and -b), show that the Wholist-Verbalizer:Text-plus-graphical
metaphor treatment sub-group has the highest post-test median, and $Sd$ distribution, of the ICS sub-groups. However, their pretest distribution is also high, thereby resulting in the relatively small $Q_{dlv}$. The text-plus-textual metaphor treatment sub-group shows little variation in distribution from the pretest to post-test. The pkpb participant performance analysis also shows that the Wholist-Verbalizer:Text-plus-graphical metaphor treatment sub-group achieved a higher score than their textual metaphor treatment counterparts, adding five participants to the upper pkpb levels (Figure:6.15-b), compared to no movement for the textual metaphor sub-group.

5.2.2 Analytic-Verbalizer

The Analytic-Verbalizer sub-group also scored higher with graphical metaphors ($mean-Q_{dlv} = 0.235$) than their textual metaphor treatment counterparts ($mean-Q_{dlv} = 0.055$) (Figure:6.9). The small $ES$ is 0.220 (Table:6D). Figure:6.11-a and -b, shows the graphical metaphor treatment sub-group has a higher post-test median and a narrower distribution than their textual metaphor counterparts. The pkpb analysis also favours the graphical metaphor instructional treatment (Figure:6.15-b), with four text-plus-graphical metaphor treatment participants progressing to the upper pkpb levels (6 to 8), while there was a downward shift of three participants from the textual metaphor treatment sub-group.

5.2.3 Wholist-Imager

The Wholist-Imager sub-group clearly scored higher with the graphical metaphor treatment. Their $mean-Q_{dlv}$ of 0.312 is 0.227 (Figure:6.9) logits higher, than their textual metaphor treatment counterparts, resulting in a median $ES$ of 0.329 (Table:6D). Given the sample size, there is a 45% chance, that the instructional treatment affected cognitive performance. The box plots (Figure:6.11-b) shows that the graphical metaphors sub-group has higher post-test median and distribution limits, than their textual metaphor treatment counterparts. Neither treatment sub-group had movement to or from the upper pkpb levels (Figure:6.15-b).

5.2.4 Analytic-Imager

Neither of the Analytic-Imager sub-groups scored well on the experiment. The text-only sub-group obtained a $mean-Q_{dlv}$ of -0.118, scoring a lower logit value on the post-test than the pretest. However, the graphical metaphor sub-group scored even lower, with a $mean-Q_{dlv}$ of -0.175 logits (Figure:6.9). The $ES$ of 0.066 (Table:6D), is negligible. The Figure:6.11-a and -b box plots, show little variation in the post-test median or distribution between the treatment sub-groups.
The graphical metaphor treatment sub-group, faired better on the pkpb analysis than their textual metaphor counterparts, losing only one participant from the upper pkpb’s, compared to minus four participants from the textual metaphor treatment sub-group (Figure:6.15-b).

5.3 Interactive affect of cognitive style and instruction

The previous two sub-sections have compared the logit values of each SCCS group or ICS sub-group with their counterparts, given the opposite instructional treatment. However, Figure:6.9 clearly shows that much more variation occurs between the cognitive style groups/sub-groups than within. For instance, the ES between the Wholist-Imager:Text-plus-graphical metaphor treatment sub-group and the Analytic-Imager:Text-plus-graphical metaphor treatment sub-group is a large 0.580. Similarly, a comparison of the former sub-group, with the Analytic-Imager:Text-plus-textual metaphor treatment sub-group, yields an ES of 0.566. As Table:6F illustrates, a medium to large ES exists for most of the cognitive style/instructional treatment interaction comparisons. The following chapter will focus on the above interaction.

Summary

The analysis of results was discussed in a tri-level manner. Firstly, within the contextual light of the environment effects discovered while running the exploratory studies (Pilot-1 and Pilot-2, see McKay,1999a, and McKay,1999b respectively). As a result, several hypotheses were developed to test whether the research objectives were met.

Secondly, the extraneous variables deemed to have influence on the findings were identified, and presented in a tabulated format, to show where modifications were required to the methodology of the final experiment thereby enhancing the possibility of correctly describing the influence of the external-conditions-of-the-learner on an individual's capacity for cognitive performance.

Thirdly, the quantitative measurement of cognitive performance was successfully achieved, utilising the power and reliability of the QUEST estimate, which draws on the well known Rasch Model (Rasch,1960) for the measurable instructional outcomes (MIOs) described in Chapter Five : Research Methodology and Experimental Design, sub-section 2.6.

However, it was the effectiveness of the evaluation of the QUEST estimate, devised through statistical power analysis, which best articulates the significance of the findings through the calculation of the effect size (Cohen,1977), thereby providing the foundation for a realistic discussion of the findings.
The purpose of the next chapter is therefore, to highlight the importance of the effects of context on cognitive performance.
Chapter Seven: Meta-Knowledge Acquisition Process

The previous chapter analysed the experimental results and their significance within the contextual framework defined for the acquisition of programming concepts. The cognitive style construct (Riding & Rayner, 1998) was shown to provide one of the most important influences on the environmental factors involved in programming knowledge construction. However, Reigeluth's conditions-of-the-learner model better addresses the myriad of complex research variables known to impact on the final outcomes.

This chapter examines the contextual issues in understanding the interactivity of instructional conditions as a meta-knowledge acquisition process, leading to the final conclusion, that it is the interaction of the integrated cognitive style construct which affects performance the most.

Although the interactive effect of cognitive style and instructional format is confirmed for the acquisition of programming concepts, there is still much to be learned about how humans process information. Nevertheless, there is indicative support from previous research to substantiate the speculative mechanisms advanced in explanation of my research discoveries.

Learning and instructional models have been proposed to cater for individual differences in learning mode (Ausburn & Ausburn, 1978; Biggs & Collis, 1982; Sternberg, 1998). They articulated the need to work with, instead of against, the human brain's natural processes for accessing, storing, and retrieving information (King, 1997).
There are two opposing theories relating to matching instruction with cognitive style. Firstly, the common belief that pictures will enhance learning performance for all students is widely held (Moonen, 1994; Stanchev, 1994), while secondly, the notion that verbal (text-based) instruction is best suited to a verbal cognitive style while pictures (graphical representation) suit an imagery-based cognitive style best (Riding & Douglas, 1993; O'Halloran & Gauvin, 1994). However:

the interactive effect between cognitive style and instructional format for adult learners shown by the findings of this research is at variance with the axiom, that enhancing instructional format with pictures or graphics will improve the learning process for imagers, and that verbalisers benefit from textual or verbal instruction best.

Early attempts during the 1950's and 1960's by psychologists researching cognitive abilities and processes produced a fragmented list of models and labels derived mainly from single experiments (Riding & Rayner, 1998). (See Chapter Two: Conceptual Framework, sub-section 4.1 Cognition and Instructional Format).

Indicative support for this counterview combines research from disparate areas. Defining how individuals process information is a complex issue, reinforced by the extensive literature on human-computer interaction. Diverse perceptions by researchers of the nature of these complex issues, and the corresponding diversity of their paradigms, has resulted in inconsistent terminologies in their representation of human-computer interaction.

The solution to this dilemma was seen to lie in an understanding of the meta-knowledge requirements for integration of the human factor's methodologies.

The subsequent sections in this chapter provide an in-depth analysis of these meta-knowledge requirements, in the light of previous educational models and research processes:

- Contextual effects
- Implementation of the research plan
- Results
- Discussion
1. Contextual Effects

Riding & Rayner (1998) argued that cognitive style is understood to be an individual's preferred and habitual approach to organizing and representing information. In an earlier 1997 study, they pointed out, that models developed from previous research on cognitive/learning styles should, more correctly, be called learning strategies. King (1997) concurred with this differentiation by describing learning style as a student's consistent preference in learning strategies. Similarly, Pask (1976) had argued that the Holist/Serialist distinction was an example of different learning strategies rather than learning styles.

However, Riding & Cheema (1991) were able to condense the earlier (learning) style constructs found in the literature into two dimensions of style to reflect an integrative model of cognitive style. (Wholist-Analytic, the mode of processing information, and Verbal-Imagery, the representation of information during thinking). They developed a computer-based test known as the Cognitive Styles Analysis (CSA) to measure an individual's position along these two cognitive continua (see Chapter Two: topic 4.3.3 Cognitive style measurement). The CSA is an improvement on the famous Witkin (1950) Embedded Figures Test, which according to Riding & Cheema (1991) measures an individual's ability (Griffin & Franklin, 1995-6) rather than style.

The evaluation of the integrated cognitive style construct and instructional strategy for adult programming learners has taken the Riding & Sadler-Smith (1992) research (with 14- and 19-year old students) another step by drawing on the Douglas & Riding (1993) methodology to divide the sample of tertiary level students into quarters using the two cognitive style continua (Wholist-Analytic and Verbal-Imagery), referred to as the single-category-of-cognitive-style (SCCS) groups. Therefore these four-SCCS groups: Wholist, Analytic, Verbalizer, and Imagery groups are used as the benchmark comparisons.

The four categories of Wholist-Verbalizers, Analytic-Verbalizers, Wholist-Imagers and Analytic-Imagers are referred to as the integrated cognitive style (ICS) sub-groups. Therefore, there were eight-ICS/instructional treatment comparison sub-groups (see Chapter Five : sub-section 3.4.).
Isolation of the variables *cognitive style* and *instructional conditions* provides the frame of reference for describing a new effect.

Nonetheless, the contextual effects may arise as generalities, which change according to the interactive relationship between an individual's capacity for the *internal-* and *external-conditions* of learning and instruction (Figure:7.1).

For that reason, the findings when expressed within the specific context of programming concept acquisition constitute the emergent paradigm in representing the abstract metaphor for "*cognitive style construct* linked to Reigeluth's model for the *conditions-of-the-learner*".

This emergent paradigm supports the contextual mechanisms involved in *meta-knowledge acquisition*:

- Learning and instructional strategies
- The question of spatial ability
- Intelligence and notational transfer
- Cognitive strategies for acquiring new knowledge
- Computer-programming concepts in analogic knowledge elements
1.1 Learning and Instructional Strategies

The relationships between learning and instruction are dynamic. The earlier view that instruction involves the control of learning processes (Shuell, 1980; Winn, 1982-a; Reigeluth, 1983-b) is typical of the research notions of the 1980's. They appear to argue for mutually exclusive models, by making a distinction between learning and instruction; in that *instruction* induces learners to use learning strategies for particular tasks, operating externally to the learner, while *learning* involves the internal processing by the learner (Biggs & Collis, 1982; Winn, 1982-a).

Meanwhile, *mental skills* were thought of as those processes that learners use productively in learning. *Imagery* is one of the key *mental skills* believed to be utilized during learning, and although most people use *imagery* as a cognitive process, only some of them are skilled in its use (McNamara, 1988).

However:

> the *meta-knowledge processing model* deduced from the emergent paradigm involves an interactive relationship between *instructional strategies* and learning.

1.2 The Question of Spatial Ability

In the past, *verbal* (or *analytic*) ability was taken to be a measure of *crystallised intelligence*, or the ability to apply *cognitive strategies* to new problems and manage a large volume of information in working memory (Hunt, 1997), while the *non-verbal* (or *imagery*) ability was expressed as *fluid intelligence* (Kline, 1991). However, as electronic courseware lends itself to integrating *verbal* (*textual*) and *non-verbal* (*graphical*) *instructional conditions* that generate novel (or *fluid*) intellectual problems, more research needs to be carried out to provide instructional designers with prescriptive models that predict *measurable instructional outcomes* for the broader range of cognitive abilities.

Therefore, the methodology for *cognitive performance measurement* used in this dissertation was designed to facilitate the prediction of whether:

> the *method of delivery* will affect *highly-verbal/low-spatial* learners, because they need a *direct notational transfer agent* (Figure: 7.2); or whether the *instructional conditions* will disadvantage *high-spatial/low-verbal* learners, because they will be less able to pick out the unstated assumptions.
Picking out these important instructional variables for some types of instructional outcomes provides appropriate instructional environments for a broader range of novice-learners by means of the:

**information-transfer-agent, thereby controlling the choice of instructional format and instructional event conditions.**

To this end, Figure:7.2 shows how isolating the key components of the instructional conditions provides the means to manipulate the method-of-delivery, which in turn may bring about a choice of information-transfer-agent.

According to Goodman (1968), the external-representation of the instructional material may require a direct notational transfer of the symbol-system used for the instructional strategy (from the external representation of the instructional material to an internalised form in an individual's memory). For instance: the graphical details in a road map directly relate to the physical environment (in a 1:1 or direct notation ratio, like the explicit representation of basic data-type rules in computer programming). Therefore, in a programming environment, another example would be that a real number must not contain a decimal point (Figure:7.2). See Chapter Two : Conceptual Framework, sub-section 1.3 Goodman's Notational Language.
On the other hand, the embedded details in an abstract metaphor are said to require a non-notational transfer process. For instance, the programming loop shown as a graphical metaphor in Figure 7.2 requires a 2:1 transfer for the non-notational characteristics of the external representation to a single internal notational representation.

Researchers have been pursuing the question of what happens when humans process abstract information (Biggs & Collis, 1982). While there have been a number of research studies conducted using younger participants, studies on the interaction of instructional strategies with adult-learners are not as common. For instance, Rosinski, Pellegrino & Siegel (1977), conducted a study designed to examine developmental changes in the semantic processing of pictures and words using younger participants (second- and fifth-graders). At both grade levels, they found that access reaction times for words were greater than for pictures and declined with age (Rosinski et al., 1977).

The meta-knowledge processing model accommodates the novice learner, regardless of age. Furthermore, as the participants for my research were tertiary students, it is now possible to evaluate whether cognitive style in adults is more entrenched.

1.3 Intelligence and Notational Transfer

Linking intelligence with notational transfer per se is not new. For instance, in Sternberg's triarchic theory, intelligence includes three elements (Sternberg, 1988:132):

"in terms of its relation to the internal world of the individual, its relation to experience, and its relation to the external world of the individual"

Therefore, it would seem that experience moderates between an individual's internal and external worlds.

The programming metaphors designed for this dissertation are deemed to serve as mediation devices between an individual's internal- and external-representations.
Kosslyn (1976) conducted studies, which involved participants manipulating imaged geometric shapes namely, cubes, squares, and lines. He suggested that images cannot simply be replays of initial unanalysed sensations, and hypothesized that the experience of an image itself arises out of constructive processes (Kosslyn, 1976:342):

"the units abstracted and interpreted during perception are stored in long-term memory in an abstract form and must be acted on by processes that serve to generate or to produce an experience of an image".

More recently, research has been able to measure the interaction between cognitive style and academic performance (Riding, Glass & Douglas, 1993:276):

"In cognitive style terms, individuals will, where possible, represent and process information in their habitual modes. Consequently, Verbalisers will translate pictorial information into word or semantic representations and Imagers will represent semantic information in mental pictures, whenever possible. The effect of this will be that, while verbal information will result in predominantly left hemisphere activity in Verbalisers, it may also produce right hemisphere activity in Imagers where the material allows this.

Riding & Agrell (1997) were able to show that academic performance of low-ability learners was affected more than the high-ability learners (with the same cognitive style), when the combination of cognitive style and subject matter were not ideal. For instance: the difference in performance between high- and low-ability learners was greater for Analytic-Imagers than Analytic-Verbalisers.

The meta-knowledge processing model separates out the method of delivery, instructional conditions, and measurable instructional outcome components. As a result, accurate prediction of novice-learner performance is now possible.

1.4 Cognitive Strategies for Acquiring New Knowledge

Cognitive strategies for acquiring new knowledge involve the use of symbolic construction to add meaning to the information-to-be-learned. However, there may be dangers associated with adding graphical enhancements to instructional material for some individuals.

Researchers have sought ways to explain how humans use imagery to facilitate learning. For instance, Wittgenstein (1963) likened the development of a language to an ancient city, with this metaphor (Wittgenstein, 1963:83):
"a maze of little streets and squares, of old and new houses, and of houses with additions from various periods; and this surrounded by a multitude of new boroughs with straight regular streets and uniform houses ".

Disagreements, where voiced, on the issue of whether the cognitive process leads to understanding (Potter & Faulconer, 1997) typically question whether the early stages of cognitive processing leads to a common abstract representation in memory. For instance, does the idea of a chair, lead to separate representations; one that is verbal (a spoken or written likeness), while the other is image-like? They were able to demonstrate that knowledge of the category of an object is associated with an abstract idea of the object, rather than directly with its name or appearance. Nevertheless, the question of whether the other knowledge an individual has about an object (like size/value, etc.) is linked to the abstract concept they have stored in memory, remains unanswered!

1.5 Computer Programming Concepts as Analogic Knowledge Elements

Computer programming involves a special category of abstract (process) concepts (for the full description, see Chapter Two: Conceptual Framework, sub-section 2.3 Concept Characteristics).

This type of concept was chosen to focus on the role of analogic knowledge involved in computer programming. The results are discussed within the context of the internal/external exchange process, drawing on Ritchey's (1980) concepts of within-item and between-item encoding elaborations.

Within-item elaboration refers to the qualitative nature of human information processing of words. The literature shows that individuals distinguish the differences between attributes of an item considered to be in the same (cognitive) subset. Therefore, superiority in recalling pictures is due to differences in the extent of within-item elaboration produced by pictures and words (Ritchey & Beal, 1980). For instance:

distinguishing the programming rules that are specific to the attributes of the DOWHILE statement shown in Figure:7.3-a.

Between-item elaboration, on the other hand, refers to imaged detail. It was previously thought that pictures and words may activate a common abstract representation in memory (Nelson, Reed & McEvoy, 1977; Rosinski et al., 1977; Potter & Faulconer, 1997).
Consequently, according to Ritchey & Beal (1980) *between-item elaboration* should be limited to enhance recall of items imaged. They believed that picture superiority holds only when the items are presented as unrelated collections. Furthermore, when the items are displayed in a category-recall manner (emphasizing the *between-item elaboration*), there are no differences between the pictures and words.

For instance:

inter-relating the *external-* nature of the (instructional) *event conditions* of the repetition statement (shown in Figure:7.3-b), with existing memories of other such items (or *internal-conditions-of-the-learner*).

However,

this evaluation of instructional treatments (*textual vs graphical metaphor*) extends the Ritchey & Beal (1980) research, by revealing the *interaction of participants' performance* and test-items on a *uni-dimensional performance scale.*
2. Implementing the Research

A series of empirical research studies were designed to explore the relationship between cognitive style and instructional format in adult learning.

Three experiments were conducted; two pilot studies (McKay, 1999a; McKay, 1999b) and a final experiment (McKay & Garner, 1999). The experiments have spanned four-years, commencing with the first pilot study in 1994, and ending with the final experiment in 1997. Overall, there was a total of over 280-participants involved in this research.

Each of the experiments consisted of four-stages:

- a cognitive style screening test
- a pretest
- the instruction period
- a post-test

The Riding & Cheema (1991) Verbal-Imagery scale was used as an independent variable to split the sample into verbal (textual) and visual (graphics) treatment groups. The pretest was used to indicate participants' prior domain knowledge of complex-programming concepts to facilitate the measurement of cognitive performance on the post-test.

Three sets of instructional booklets were created for the experiments (see Volume: 3). The latter two listed below represent the second independent variable upon which the sample was then split into instructional treatment groups, thus forming a 2 x 2 factorial design.

- a self-paced tutorial manual
- textual-instructional-material (Treatment-1)
- textual instructional-material enhanced with graphical-cueing-techniques and analogies (Treatment-2)
For full descriptions of these instructional booklets, see Chapter Five, sub-section 2.3 Defining the Learning Content.

In *Pilot-1* (McKay,1999a), and *Pilot-2* (McKay,1999b), the *post-test score was used as the dependent variable*, with *post-instruction-performance* measured by subtracting the *pretest scores from the post-test*. In *Pilot-2* (McKay,1999b) and the *final experiment* (McKay & Garner,1999), the QUEST estimate was used to measure *cognitive performance on specified instructional outcomes*.

*Item Response Theory* describes the assessment method used by the QUEST estimate process. It compares actual patterns of responses from the interactions of *test-items* with *participants performances*, compared with a model pattern. This becomes the QUEST *fit-statistic*. Unusual patterns can be investigated. (For the full description of how QUEST was used to evaluate participants' performance, see Chapter Six : Results, section 3. Tools and Analysis.) Central to the QUEST estimate is the measurement model developed in 1960 by *Georg Rasch*, a Danish statistician. QUEST develops an *uni-dimensional scale* with equal intervals along each axis to measure *performances* and *test-items* together.

This scaling feature enables a developmental sequence of *learning tasks to be arranged from simple to more complex*, thereby *refocussing the Structure of the Observed Learning Outcome (SOLO) taxonomy* (Biggs & Collis,1982).

It is also possible to locate an individual at different skill levels along this scale (McKay & Garner,1999). The assessment of particular skill levels relies on choosing tasks that can provide evidence, which effectively distinguishes between those who have the required programming knowledge and those who have not.
3. Results

The experiments were conducted using tertiary-level adult learners:

**to investigate the interactive effect of cognitive style and instructional material** (enhanced with metaphors), in the **acquisition of abstract programming concepts**.

In the first two experiments, the sample (45-participants for Pilot-1; and 37-participants for Pilot-2) was only split on the Riding & Cheema (1991) **Verbal-Imagery cognitive style dimension** (the mode of representing information during thinking).

While Pilot-1 was an adaptation of the Bagley (1990) study on **structured versus discovery instructional formats** for improving the learning of programming concepts by **novice and experienced adult learners**, Pilot-2 was redesigned to investigate the interactive effect of **cognitive style and instructional strategy** (**textual/graphical metaphors**) for learning **abstract computer-programming concepts** by **adult learners**.

It was found that **graphical representations** of these abstract concepts (Figure:7.3-b), when added to **textual learning material**, have a positive effect on **learning outcomes** (McKay,1999b). Moreover, the results from Pilot-1, support the Bagley (1990) hypothesis that **novice computer-programmers** prefer a structured approach to learning abstract programming concepts, whereas **experienced computer-programmers** perform best with unstructured material.

Furthermore, Pilot-1 extended the Bagley research to show:

that the **experienced** participants with the **text-plus-graphics instructional format** performed better than their **text-only counterparts**. More specifically, there was strong evidence in both Pilot-1 (with dichotomous scoring), and Pilot-2 (with dichotomous and partial credit scoring), that the best performances were achieved by the **Verbalizers** using the **text-plus-graphics instructional material**, and a weaker confirmation that the **Imagers** performed best using the **text-only instructional material** (Figure:7.4).
However, this result contradicts popular belief, that *Verbalisers* learn best from *words* and *text* (Figure:7.3-a), and that *Imagers* learn best from *pictures* or *graphic representations* (Douglas & Riding, 1993; O’Halloran & Gauvin, 1994).

Even though different measurement methodologies were used for both experiments (*statistical means* for Pilot-1, and the *QUEST Interactive Test Analysis System* for Pilot-2); the findings were at variance with to the expected outcome. Subsequently, to confirm the *interactive relationship* between *instructional format* and *cognitive style*, the third and final experiment was conducted on a large data set (195-participants). The increased sample size facilitated the analysis of the effects of the *Wholist-Analytic cognitive style dimension*, and the *gender variable*.

The methodology (from Pilot-2) was modified to reflect the need for:

- increased number of test-items
- increased variance of instructional outcome difficulty
- changes to the sequencing of pre-experiment instructional material

Analysis of the *SCCS groups* based on their *mean-Qdly* (See Chapter Six : Results, topic 4.2.1 Performance analysis, and Figure:6.9), indicated that all groups performed better with the *graphically enhanced instructional treatment* (Treatment-2).
Results

Table: 7A  Performance of Instructional Treatments

<table>
<thead>
<tr>
<th>SCCS Groups</th>
<th>Treatment-1</th>
<th>Treatment-2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean Qdlv</td>
<td>Box Plot</td>
</tr>
<tr>
<td>Wholist</td>
<td>0.080</td>
<td>0</td>
</tr>
<tr>
<td>Analytic</td>
<td>-0.054</td>
<td>-7</td>
</tr>
<tr>
<td>Verbalizer</td>
<td>0.063</td>
<td>-3</td>
</tr>
<tr>
<td>Imager</td>
<td>-0.040</td>
<td>-4</td>
</tr>
</tbody>
</table>

ICS Sub-groups

<table>
<thead>
<tr>
<th>SCCS Groups</th>
<th>Treatment-1</th>
<th>Treatment-2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean Qdlv</td>
<td>Box Plot</td>
</tr>
<tr>
<td>Wholist-Verbalizer</td>
<td>0.073</td>
<td>0</td>
</tr>
<tr>
<td>Analytic-Verbalizer</td>
<td>0.055</td>
<td>-3</td>
</tr>
<tr>
<td>Wholist-Imager</td>
<td>0.085</td>
<td>0</td>
</tr>
<tr>
<td>Analytic-Imager</td>
<td>-0.118</td>
<td>-4</td>
</tr>
</tbody>
</table>

However, the Wholist and Verbalizer groups clearly benefited most from inclusion of the graphical-metaphors. Although the ES between instructional treatment groups is small (~0.2), all analysis measurements show a preference to the Treatment-2 material (top half of Table: 7A). This result is contrary to predictions from the Riding & Ashmore (1980), Riding, Buckle, Thompson & Hagger (1989), and Riding & Buckle (1990) findings. The Analytic and Imager groups although showing only modest improvement with Treatment-2; the Treatment-1 group actually performed lower on the post-test than the pretest relative to the other participants (Figure: 6.9).

The QUEST data analysis suggested there were trends of the form:

**Verbalizers** learn abstract concepts differently from Imagers and benefit from the text-plus-graphical metaphor enhanced instructional format. Furthermore, Verbalizers learn how to apply abstract concepts in varied contexts differently from the Imagers. They appear to be better at transferring their conceptualisation’s of the graphical representations into new computing contexts. Therefore, Verbalizers would learn new programming concepts better with a text-plus-graphical metaphor than the text-plus-textual metaphor material.

Given the relatively poor performance of the Analytic and Imager SCCS groups, it is not surprising that the Analytic-Imager ICS sub-groups performed badly. Their mean-Qdlv's (see Figure: 6.9) are both negative with the Treatment-2 sub-group (-0.175) obtaining a lower value than their Treatment-1 counterparts (-0.118). This would suggest that an Analytic-Imager would perform best with the textual treatment.
The other three-ICS sub-group combinations performed better with the graphical enhanced material (Treatment-2) than with the textual treatment (see Figure:6.9, and lower half of Table:7A). However, the Wholist-Imager and Analytic-Verbalizer groups have performed better than the Wholist-Verbalizer group. Based on the SCCS analysis, one would have expected the latter group to have out-performed the groupings, which involved the Analytic or Imager dimensions. The negligible ES(0.130) (Table:6D) between the Wholist-Verbalizer:Treatment-1 and Treatment-2 sub-groups may be partially due to a medium ES (0.318) between these sub-groups on the pretest. The Treatment-2 pretest mean was 0.201 logits higher, perhaps indicating that a number of these participants had some programming experience, limiting the improvement possible on the post-test, and thereby lowering the Qdlv performance measurement. Despite this concern, the ICS sub-group results emphasize that both cognitive dimensions must be considered for developing tailored instructional strategies.

Although clear trends are apparent in the SCCS and ICS comparisons of cognitive style group counterparts using the alternative treatments it is nevertheless, the interactive effect of cognitive style and instructional treatment that show the most variation in performance. The ES size, when comparing one cognitive grouping with another, using the opposite instructional treatment shows a medium to large ES for the majority of cases (Figure:7.5).
For instance:

*it is clear that a Wholist-Imager given graphically enhanced material would clearly outperform an Analytic-Imager using text-only instructional material (ES=0.566).*

The significance of these findings justified the proposed meta-knowledge acquisition model for exploring the primary mechanisms, and their environmental consequences. (For the full listing of research questions, see Chapter One : section 4.).

4. Discussion

The principal observations that emerge from this research are:

- the interactivity of instructional conditions’ components.
- the interaction of the ICS sub-groups, and instructional treatment, on performance (or instructional outcomes).

This research has been able to show how pictures interact with particular cognitive styles, by measuring the instructional outcomes for:

- content-specific knowledge within the content area of computer programming
- content-specific knowledge outside the content area of interest
- knowledge of generic skills applying across several content areas

When describing how novice-programmers learn basic concepts, it is not as simple as saying that Verbalizers perform best with *text* and Imagers with *pictures*. In fact, these results indicate the opposite is true for learning complex programming concepts. Verbalizers clearly performed better with *graphics-enhanced-material* in all three experiments and Imagers have limited or no benefit from the inclusion of *pictures* in their *instructional material*. However, this only looks at one cognitive dimension, and therefore, the interpretation needs to reflect the complexity of the *instructional conditions* framework, in which the interactive effect of the complete cognitive style construct and *instructional format* (enhanced with *text* and *graphics*) can be disambiguated.
For instance:

both cognitive style dimensions of Wholist:A and Verbal:I respond better than the W:Analytic and V:Imager to instructional material that contains graphics alone.

Therefore, consideration must be given to the type of cognitive skill required to achieve the instructional outcomes. For instance, whether it is a matter of understanding just the concepts and principles (an intellectual skill), or of identifying the procedural sub-tasks (a cognitive strategy).

The results from both the Wholist, Analytic and Verbalizer SCCS groups suggest that particular individuals, who receive only textual instruction that requires them to make between-item elaborations (abstract programming concepts), will be unable to process the information. They will be unable to perform the cognitive tasks, which require a non-notational transfer process.

For instance:

recognising the unstated assumptions relating to tasks that require procedural knowledge.

In the between-item example (Figure:7.6-a), understanding the semantic verbal representation of the abstract programming rules requires the novice to translate the external-representation (non-notational characteristics) of the text into separate internal-representations as single rules (direct notational associations).
However, from the findings it may be speculated:

**whether there is a direct association of the representation of a programming concept name or image, given in instructional material, with the name and appearance of the programming concept represented in an individual’s memory.**

While on the surface, the cognitive process involved in gaining declarative knowledge appears straightforward, there is likely to be a combination of logical reasoning (from the reading of the words) and spatial relations (from the internalised notational transfer).

The results from the Imager SCCS group suggest that particular individuals who receive only pictures or graphics that require within-item elaborations will not notice enough detail in the graphical representations to perform the required notational transfer process. For instance:

**picking out the declarative knowledge elements that are required for learning basic rules.**

However, in the between-item example (Figure:7.7-b) the visuo-spatial representation (Rolandelli, Sugihora & Wright,1992) requires the novice to comprehend from the pictures (or graphical-metaphors) the declarative knowledge relating to: input data requirements, processing attributes, and output characteristics. Therefore, the aggregated view afforded by the pictorial representation may produce an internal (haptic-like) inability to pick out the isolated facts necessary for the notational transfer to occur.

The answers may well lie in the type of relationship between the way an individual thinks of things seen, and their natural mode of processing that information. Consequently, it is only on the comparison of the ICS sub-groups, that the effects of the cognitive style construct on measurable instructional outcomes for complex programming concept acquisition can be distinguished.

The following mechanisms explain how the participants dealt with the instructional format:

- Information processing
- Internal/external exchange process
4.1 Information Processing

An explanation for how the cognitive style construct (Riding & Rayner, 1998) interacts with particular abstract or procedural programming knowledge tasks may lie within the relationship of the instructional conditions' components, as shown in Figure: 7.7.

For instance:

Given that individuals' performances will vary on the strength of their cognitive style, it was hypothesized there would be some type of interactive effect of the graphical metaphor.

If so:

- can the explanation be found using between-item and within-item elaborations, and in particular, for the acquisition of abstract programming concepts?
- can visual metaphors, used as an internal/external exchange process, have the same interactive effect (for some novice learners) in the programming environment?
Support for the internal/external exchange process can be found in the work of Levin (1981-a). The basic message conveyed by combining text and graphics (pictures) is twofold (Levin, 1981-a:217):

"First, the major impact of pictures on prose-learning facilitation is derived from their transformation function (internalised form) rather than from their representation function (external form). Second, much larger facilitation differences between visual illustrations and visual imagery are associated with the representation function than with the transformation function" (bolded text included by the author).

Examination of the test-item responses, indicates that novice learners are transferring the external-representation (what they see) into their internal-representations (how they think about it).

4.2 Internal/External Exchange Process

A phenomenon that occurs within a learner during a learning experience is referred to here as:

the internal/external exchange process; it has the capacity to activate the learning process, by stimulating the reception of the to-be-learned material.

An internal/external exchange process occurs when an individual processes the instructional strategy (textual/graphics), reprocessing the external-representation using their inherent Wholist-Analytic cognitive style. However, as cognitive style is a continuum, it is quite likely that its strength will differ from person to person, thereby creating a complex variable. Figure:7.7 shows how the internal/external exchange process is believed to link the two components (learner characteristics and instructional format) of the instructional conditions as described by Reigeluth (1983-b).

The most successful instructional conditions occurred with the Wholist-Verbalizer subgroup, given the graphical metaphors (based on the highest post-test mean-Qlv). However, their mean-Qdlv performance measure (Figure:6.9) is only third best, due to a relatively high pretest mean-Qlv. Still, their post-test performance indicates the highest programming knowledge of the ICS sub-groups.
Even though this sub-group's verbal style of thinking indicates an ability to perceive segmented detail in what they see they were able to draw on their inherent mode of processing information (their Wholist-A dimension) to activate their notational transfer ability. Thereby dealing with the totality (or non-notational characteristics), of the graphical metaphors without the semantic verbal representation of a textual metaphor, to transfer the programming concepts into discrete segregated parts, for their analytical thinking mode (their Verbal-I dimension).

This ICS sub-group may have dealt with the graphical metaphors using their capacity for logical reasoning (Douglas & Riding, 1993). This conclusion would imply use of their verbal (or semantic) tendency for representing information, while thinking about what they see (Figure: 7.8-a), picking out the programming knowledge as separate (notational) conceptualized elements and thereby capitalising on their Wholist mode of processing information to internally translate the notational representation into a non-notational form.

Although the E5 is small to negligible (0.130), Table: 7A shows that the Treatment-2 sub-group out-performed their Treatment-1 counterparts. This is contrary to expectations, with the textual treatment sub-group predicted to perform better, due in part to their ability to keep a balance of the wholeness of the programming concepts, together with the segregated parts of those concepts-to-be-learned. It can be said Wholist-Verbalizers were unable to transfer the analytic nature of the semantic verbal representation of the textual-metaphors into the non-notational representation required to process the abstract nature of the programming concepts (Figure: 7.8-b).
The most unsuccessful instructional conditions occurred with the **two Analytic-Imager sub-groups** (Figure:6.9), with the **graphical-metaphor instructional treatment group** performing worse than their **Treatment-1 counterparts**. It was expected that the **former sub-group** would perform better due to their requirement for an approximation of the whole view (Riding & Caine, 1993) of the programming concepts-to-be-learned. The **graphical metaphor** was intended to compensate for their lack of wholeness in processing mode (their **Analytic-I dimension**), and to enhance their ability to detect the separate attributes of the **pictorial representations** (their **A-Imager dimension**).

However, the aggregate (**Imager**) style of thinking of this **ICS sub-group** may prevent them from accessing their natural (**Analytic**) mode of processing information. They are, therefore, incapable of dealing with the **content-specific knowledge** (or notational elements), derived from the **graphical metaphors** (Figure:7.9).
The **Analytic-Verbalizer sub-group** given the graphical-metaphors (Figure:7.10-a) were more successful than their counterparts receiving the *textual-metaphors* (Figure:7.10-b). Although it was expected they would be limited by their *W-Analytic dimension*, preventing them from not having the means to process a whole view of the programming concepts. The results show they were able to correctly apply an *internal/external exchange process*, and thereby benefit from their *W-Analytic ability* to pick out discrete elements from the *external-instructional format*, and transfer them into a conceptualized whole. One piece of evidence for this was the upward shift of *four participants*, into the upper programming knowledge performance levels. Their counterparts receiving the *textual metaphors*, by contrast, registered a downward shift of *three participants* (Table:7A).

There is further evidence that the *thinking style dimension of a novice-learner* may have some influence over the mode of processing information. For instance:

> the thinking process involved to segregate the *imbedded parts* from a *graphical-metaphor* in a *verbal manner* (Figure:7.10-a) renders an Analytic-Verbalizer more able to transfer this disembedded detail, with their *W-Analytic mode of processing* for internalising the information. This suggests there is an *internal-external exchange process* taking place while thinking, affecting the eventual mode of processing.
Conversely, in the case where a novice uses a \textit{verbal thinking style}, and when the notation of the \textit{concepts-to-be-learned} is \textit{textual} (Figure:7.10-b), their \textit{W-Analytic} processing mode is ineffective.

This suggests that when the notation of the \textit{instructional format} does not require a novice to make the \textit{internal/external exchange transfer} while thinking about abstract events, the \textit{W-Analytic} novice cannot easily draw on their inherent processing mode.

The performance of the final \textit{ICS sub-grouping} is also interesting with the \textbf{Wholist-Imagers} with the \textit{graphical metaphors} (Figure:7.10-a) showing the highest \textit{mean-Qdlv}, and thereby achieving the best performance improvement of all groups (Figure:6.9). They out-performed their counterparts with the \textit{textual metaphors} (Figure:7.10-b), with a medium \textit{ES} of 0.329 (Table:7A) and clearly out-performed other \textit{ICS sub-groups}; with a large \textit{ES} compared to both \textit{Analytic-Imager} treatment groups (Figure:7.5).

Although the \textit{Wholist-Imager} sub-groups both had positive \textit{Qdlv}'s, neither sub-group had increased representation in the upper \textit{programming knowledge performance bands} (\textit{pkpb}'s) (Table:7A). This \textit{cognitive style} could not apparently achieve the full \textit{procedural knowledge levels} associated with complex programming knowledge acquisition. It was anticipated their \textit{W-Imager} thinking mode would compensate for a lack of analytic ability or processing skills (from their \textit{Wholist-A} dimension) in analysing the finer details of programming concepts-to-be-learned.

Furthermore, these findings confirm the notion of a \textit{relationship} between the \textit{style of thinking} and the \textit{inherent mode of processing information}.

For instance:

\begin{quote}
\textbf{in the case of the Wholist-Imager, the mental images derived through the internal/exchange process, while thinking, were able to build up enough of an aggregated view to satisfy their Wholist-A mode.}
\end{quote}

This relationship also supports Kosslyn, Maljkovic, Hamilton, Horwitz, & Thompson (1995), by showing that an inherent \textit{Wholist-A} can arrange the parts of an abstract programming concept by storing them as descriptions from an \textit{image} (using their left hemisphere) as well as arranging them in a \textit{logical manner} (using their right hemisphere).
Summary

The analysis of meta-knowledge required for the acquisition of complex programming concepts has uncovered a number of speculative mechanisms to predict performance from dual-coded instructional strategies. Therefore, it is proposed that the meta-knowledge processing model provides an ideal framework for describing a new effect in acquiring programming concepts, in terms of analogic knowledge elements. These mechanisms were identified as: learning and instructional strategies, spatial ability, intelligence and notational transfer, and cognitive strategies for acquiring new knowledge.

A more general interpretation of the findings suggests the possibility of conjecture regarding the implications of including cognitive style construct within the SOLO taxonomy in extending the age continuum to include adult learning characteristics.

In closing, there are two interesting factors for the acquisition of programming concepts, which emerge from these findings.

Firstly, the most striking, is the suggestion, that in devising a prescriptive model for expressing concepts of computer programming in terms of content specific knowledge elements, there is a need to provide a notational representation of the instructional strategy in a text-only format, especially for the Analytic-Imagers.

Secondly, all the other ICS sub-groups (which includes the Verbalizers), perform better with a mix of text and graphical-metaphors, which in turn relates to a combination of direct notational and the indirect non-notational characteristics of between-item elaborations.

Therefore, it appears to be the interactivity of the instructional conditions' components, and the interaction of the integrated cognitive style (ICS) attributes that emerge as the most striking observations.

The next chapter highlights the implications, which flow in a natural sense from this research, and proposes a computerised learning shell, which would cater for individuals' cognitive style construct, to maximise cognitive performance.
Chapter Eight: Customising the Learning Environment

The previous chapter discussed the research results in the light of the contextual environment pertaining to the acquisition of computer programming skills. The final conclusions drawn from these findings indicated that, when describing the interactive effect of an instructional strategy on the means which individuals think of what they see:

- **Verbalizers** perform best when given an instructional format enhanced with **graphical metaphors**
- **some Imagers** may respond better with **text-only material**

Furthermore, when describing the interactive effects of the inherent mode of processing information and instructional format:

- **Wholists** perform better when given **graphical metaphors** than when receiving the **text-only variety**
- **Analytics** also performed better with the **graphical metaphors**, although not as well as the **Wholists**

However, a more detailed analysis of results reveals a more complex explanation. It is evident that:

when given a **graphics enhanced instructional strategy**, particular combinations of **cognitive style construct** have the potential to perform much better than others
In particular:

the largest effect size for the integrated cognitive style groupings was accomplished by the Wholist-Imagers and Analytic-Verbalizers

As expected from the exploratory study results, and confirmed in the final experiment:

Analytic-Imagers perform poorly with the graphics format

This chapter proposes the application of the research findings, presenting a theoretical approach to implementing a computerized learning shell.

1. Application of the Meta-Knowledge in a Learning Shell

Installing the Cognitive Style Analysis (CSA) (see Chapter Two: topic 4.3.3), as a front-end courseware module is seen to provide the novice learner with advice as to their cognitive style construct. Armed with information relating to different ways individuals may wish to receive instruction, it is now possible to direct them to an instructional strategy of their choice (Figure:8.1). At the very least, benefits may be derived from offering novice learners alternative external representations of learning content.
My findings, and in particular, the observed *interactive effect* of the *cognitive style construct* and *instructional strategy*, may be unique to the acquisition of programming concepts. Therefore, researchers/trainers will need to run an extensive pilot study programme to identify the *interactive effects* within their specific learning domain. In addition, the instructional material does not need to be limited to a *textual/graphical* comparison, but could be applied to any two or more instructional treatments of any kind. For instance: a *structured* versus *exploratory strategy*.

This thesis has clearly identified the complexity of the environment (Figure:8.2), and has outlined prospects for a *customised learning shell*, based on *meta-knowledge* derived from the findings of this research. Progress is thus possible in linking research outcomes to actual learning contexts. The advent of computerized courseware options dictates a need for innovative *instructional strategies* to articulate the *visual (pictorial)* approach to instruction. However, as this work has shown:

> **not all individuals will cope effectively with a graphical environment**

We do not as yet fully understand the effects of computerized learning for the population at large. The move to a global economy will require all nations to expand their training budget, while recognising that the cost effectiveness of such training must reflect differences in individual cognitive styles. The findings of this research offers new insights and opportunities for individualized instruction.
2. Instructional Science Perspective

The *internal/external exchange agent* mechanism (see Figure:7.3) is believed to advance instructional science, by offering the basis for new interpretations of classical research with *adult novice learners*. The significance of this mechanism in other domains (younger learners) is problematic, but the *meta-knowledge acquisition process* underpinning the *exchange agent mechanism*, is seen to have direct relevance to such domains.

Successful *instructional outcomes* will be more likely for a broader range of adult-novice-learners because of their entrenched approach to learning new concepts. Therefore, we may now have the potential to identify and emulate a mix of *cognitive styles* not previously catered for.

While this chapter outlined the application of a *meta-knowledge processing model*, the next chapter reviews the research outcomes in a tabular format, to reinforce the significance of results and to render transparent the complexity of the issues encountered.
Chapter Nine: Summary of Research Claims

The previous chapter put forward a means of implementing a *computerized learning shell* that emulates contextual environments appropriate to a broad range of adult-novice-learners. The accuracy of the *QUEST estimates* in validating specific learning propositions offers the prospect of categorising prior knowledge requirements of new learning situations.

In summary, it is speculated that:

- the *conditions-of-the-learner* has the capability to unlock prior-domain-knowledge, or intellectual-skills, when consideration is given to an individual's *notational transfer ability*
- an individual's *notational transfer abilities*, provides a suitable context for unlocking particular types of *prior-domain-knowledge*
- the proposed *computerized learning shell* provides *instructional mechanisms* to unlock an adult-learner's immensely rich knowledge base
There are three ways to describe the type of activities, which may derive benefit from these findings:

- The first, based on rejection of the earlier premise that **Verbalizers** benefit from *text-only*, and **Imagers** from *pictorial* instructional strategies, proposes to recall previous research in the light of *internal/external exchange agent mechanisms*, and thereby re-stimulate the debate on how **adults learn best**.

- The second, relates to the possibility of moving towards a *more tailored learning environment*, which responds to economies of scale(*), as well as individuals' needs.

- The third proposal involves formalisation of the emergent paradigm for structured learning environments using agent technology for *meta-knowledge processing*.

(*) Using the term *economies of scale* the author is referring to cost effective training materials which meet instructional objectives for the organizational stakeholder.
Table: 9A  Implications for Refocussing Research

<table>
<thead>
<tr>
<th>Research Outcome</th>
<th>Thesis Section</th>
<th>Thesis Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>The evaluation of the integrated cognitive style construct and instructional</td>
<td>Chapter Seven</td>
<td>p.247</td>
</tr>
<tr>
<td>strategy for adult-programming-learners has taken the Riding &amp; Sadler-Smith</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(1992) research (with 14- and 19-year old students) another step.</td>
<td>1. Contextual Effects</td>
<td></td>
</tr>
<tr>
<td>This evaluation of instructional treatments (textual vs graphical metaphor)</td>
<td>1.5 Computer</td>
<td>p.253</td>
</tr>
<tr>
<td>extends the Ritchey &amp; Beal (1980) research, by revealing the interaction of</td>
<td>Programming</td>
<td></td>
</tr>
<tr>
<td>participants' performance and test-items on a uni-dimensional performance scale.</td>
<td>Concepts as</td>
<td></td>
</tr>
<tr>
<td>Pilot-1 extended the Bagley research to show: the experienced participants with</td>
<td>Analogic</td>
<td></td>
</tr>
<tr>
<td>the text-plus-tables instructional format performed better than their text-only</td>
<td>Knowledge</td>
<td></td>
</tr>
<tr>
<td>counterparts. However, contrary to popular belief that Verbalizers learn best</td>
<td>Elements</td>
<td></td>
</tr>
<tr>
<td>from words and text (Figure: 7.3-a), and that Imagers learn best from pictures or</td>
<td></td>
<td></td>
</tr>
<tr>
<td>graphic representations (Douglas &amp; Riding, 1993; O'Halloran &amp; Gauvin, 1994)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>There was strong evidence in both Pilot-1 (with dichotomous scoring) and Pilot-2</td>
<td>3. Results</td>
<td>p.257</td>
</tr>
<tr>
<td>(with dichotomous and partial credit scoring), that the best performances were</td>
<td></td>
<td></td>
</tr>
<tr>
<td>achieved by the Verbalizers using the text-plus-tables instructional material,</td>
<td></td>
<td></td>
</tr>
<tr>
<td>and a weaker confirmation that the Imagers performed best using the text-only</td>
<td></td>
<td></td>
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<tr>
<td>instructional material (Figure: 7.4)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The interactive effect of cognitive style and instructional treatment shows the</td>
<td>3. Results</td>
<td>p.260</td>
</tr>
<tr>
<td>most variation in performance.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1. Refocussed Research

The research outcomes described in this thesis justify revisiting earlier work, as follows:

*Conversation theory* (Pask, 1972), *meaningful associative links* (Schank, 1975); *assimilation-to-schema* (Sternberg, 1977); *within-item elaboration* (Ritchey & Beal, 1980); *associative learning* (Levin, 1981-a); *extending human memory capacity* (Baddeley, 1982, 1990); and *Structure of the Observed Learning Outcome* (Biggs & Collis, 1982).

Table: 9A highlights extensions to previous research and identifies some of the benefits of utilising the power of QUEST to predict performance.

The *cognitive performance measurement techniques* used by the QUEST estimate, for this dissertation permits an empirical comparison of the *interactive effect of the cognitive style/instructional format* variable, that is concentrated, accurate and capable of being replicated in other learning environments.
Moreover, combining the nature of the specific task-related activities (*measurable instructional outcomes*, referred to earlier as MIO's, in Chapter Five: Research Methodology and Experimental Design, sub-section 2.6), with the impact of the *cognitive style construct*, extends the range of the SOLO (Structured Observed Learning Outcome) taxonomy (Figure:9.1), to include adults (or the novice learner). The combined effect is to endorse the Biggs & Collis (1982) notion of endogenous limits to learning governed by process factors residing in the learner.

More work is needed by researchers to develop the components left as blank cells in the matrix proposed in Figure:9.1 to include the impact of the *interactive effects* of the *cognitive style construct* on the SOLO taxonomy.
2. Customised Learning Process

Given the demonstrated success of the computerized Cognitive Styles Analysis (CSA), (see Chapter Two: Conceptual Framework, topic 4.3.3) there are now reliable mechanisms to provide beneficial flow-ons for the training and development sectors. Table:9B lists some of the benefits of a reliable, easy to administer measure of cognitive style construct.
3. Benefits of Meta-Knowledge Acquisition

This research will be of interest to educators, cognitive psychologists, communications engineers and computer scientists specialising in computer-human interactions. The in-depth analysis provides a better understanding of the interactive effects of the cognitive style construct and instructional format on the acquisition of abstract concepts, involving spatial relations and logical reasoning (Table:9C).
Table 9D Strategic Knowledge Discovery Process

<table>
<thead>
<tr>
<th>Research Outcome</th>
<th>Thesis Section Chapter Seven</th>
<th>Thesis Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>The QUEST data analysis suggested there were original trends: Verbalizers learn abstract concepts differently from Imagers; they benefit from the text-plus-graphical metaphor enhanced instructional format. Furthermore, that Verbalizers learn how to apply abstract concepts in varied contexts differently from the Imagers. They appear to be better at transferring their conceptualizations of the graphical representations into new computing contexts. Therefore, Verbalizers would learn new programming concepts better with a text-plus-graphical metaphor format than the text-plus-textual metaphor material.</td>
<td>3. Results</td>
<td>p.259</td>
</tr>
<tr>
<td>Their mean-QdLV's (see Figure 6.9) are both negative, with the Treatment-2 sub-group (-0.175) obtaining a lower value than their Treatment-1 counterparts (-0.118). This would suggest that an Analytic-Imager would perform best with the textual treatment.</td>
<td>3. Results</td>
<td>p.260</td>
</tr>
<tr>
<td>There are two interesting factors for the acquisition of programming concepts which emerge from the findings: Firstly, and perhaps the most striking, is the suggestion, that in devising a prescriptive model for expressing concepts of computer programming in terms of content specific knowledge elements, there is a need to provide a notational representation of the instructional strategy in a text-only format, especially for the Analytic-Imagers. Secondly, all the other ICS sub-groups (which includes the Verbalizers) perform better with a mix of text and graphical metaphors, which in turn relates to a combination of direct notational and the indirect non-notational characteristics of between-item elaborations.</td>
<td>4.2 Internal/External Exchange Process</td>
<td>p.270</td>
</tr>
</tbody>
</table>

Any measurement of cognitive performance must sooner or later deal with the issue of how best to account for prior domain knowledge. Implementing objective measurement techniques (Table 9D) such as the Rasch Model provides a reliable and robust methodology, which is replicable. See Chapter Six: Results, topic 3.1.2 QUEST output displays, for discussion, and the Appendix for the QUEST Item Analysis Results.

The experimental design provided a three level discovery process to better articulate:

- the fusion of strategic knowledge required for dealing with the instructional strategies
- acquisition of knowledge using measurable instructional outcome and learner characteristics
- knowledge of the innate environmental factors which influence the instructional outcomes
Meta-knowledge has been identified as the golden key to unlock verbal/visual instructional strategies.

"... ....... However, on the second time round, she came upon a low curtain she had not noticed before, and behind it was a little door about fifteen inches high: she tried the little golden key in the lock, and to her great delight it fitted!" Carroll (1907:7)


Bagley, C.A. (1990). *Structured Versus Discovery Instructional Formats for Improving Concept Acquisition by Domain-Experienced and Domain-Novice Adult Learners*. Published as partial fulfillment of the requirement for the Degree of Doctor of Philosophy, University of Minnesota, Faculty of the Graduate School, Minnesota.


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Izard, J. (1999). Some potential difficulties in educational research studies (and how to avoid them), Paper written for the *Third Elementary Education Project,* Philippines.


predictability in theories of instructional design: Lessons from science. 
*Educational Technology*. **37**(January-February),27-34.


Lukose, D. (1992). *Goal Interpretation as a Knowledge Acquisition Mechanism.* Published as Doctor of Philosophy, University of Deakin, Faculty of Science and Technology, School of Computing and Mathematics, Victoria, Australia.


Agency on Phase One (Vol. March, 35 pp) Assessment Research Unit, Faculty of Education and Continuing Studies, University of Birmingham: United Kingdom.


Smith, P. (1998). *The Development and Evaluation of a Glass-Box Interpreter for Teaching Novice Programmers*. Published as Doctor of Philosophy, University of Deakin, Faculty of Science and Technology, School of Computing and Mathematics, Victoria, Australia.


Appendix

To aid the reader's comprehension of the research methodology, the Appendix contains the critical items referred to in the text.

Contents Listing

- **Appendix Item No:1**
  Invited Conference Paper

- **Appendix Item No:2**  Marking Scheme

- **Appendix Item No:3**
  Programming Knowledge Performance Band (pkpb) Analysis Tables

- **Appendix Item No:4**
  QUEST Test-Item Analysis Results

- **Appendix Item No:5**
  QUEST Participant(Case) Statistical Estimates

- **Appendix Item No:6**
  QUEST Participant(Case) Estimate Table : In Estimate Order (All on All)

- **Appendix Item No:7**  Cohen's Statistical Power Table No: 2.3.2

The full complement of QUEST estimate (zipped ASCII files) are provided in Volume:2. These files can be accessed from the enclosed 2HD DOS formatted 3.5"disk (see pocket attached to back cover of thesis). A suitable conversion for quality output is: **Courier New, Font Size-8, single-spacing, and a page set-up for wide output.**
The Complexities of Visual Learning: Measuring Cognitive Skills Performance

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Technology now provides the means to produce individualized instructional packages with relative ease. Multimedia and Web courseware development accentuate a highly graphical (or visual) approach to instructional formats. Unfortunately, in some quarters, little attention is given to the effectiveness of screen-based visual stimuli. Our students are just expected to be visually literate!

However, visual literacy is much harder for some people than for others.

This paper discusses the implications of the visual learning environment and the role instructional science has to play in designing instructional strategies to cater for differences in learning mode. It represents a synthesis of doctrines from instructional design, computer science and cognitive psychology; drawing together cognitive styles research from Britain, educational research and concept learning models from the USA, and state-of-the-art cognitive skills assessment from Melbourne, Australia. The central focus of this complex issue is the cognitive performance skills management. The interactive relationship between cognitive style and instructional format is discussed. Measuring cognitive skills performance is now possible in a manner that conforms to scientific principles, providing an objective and precise measurement of learners’ behaviour on a fully calibrated assessment instrument called the QUEST Interactive Test Analysis System.

Keywords: cognitive performance skills management, visual learning environment, interaction of cognitive style and instructional format, acquisition of programming concepts, instructional design

1. Introduction

There is debate among researchers over the significance of an individual's cognitive style, on their ability to learn new concepts. The majority of researchers believe there is an interactive effect, and instructional design principles dictate that we need to implement strategies to accommodate different modes of learning [1, 2, 3]. Various researchers have proposed that verbal (text-based) instruction suits the Verbalizers best, and that pictures (graphical representation) suit the Imagers [4, 5]. While there are many valuable contributions that have progressed effective use of media in teaching and learning [6, 7], there are no courseware design models that cater effectively for the differences in cognitive style.

2. Background

Reactions of adult learners to self-paced learning materials for the acquisition of programming concepts were studied in an Australian University context [8, 9]. The data were collected from several groups of undergraduate business students. The data analysis sought to identify which instructional strategy works best, for each identified cognitive style. The results clearly show there is an interaction between cognitive style and instructional format. However, some of the results are contrary to the expectations; the most striking of which is:

| Verbalizers will benefit most from inclusion of pictures in their instructional material |
| Imagers may in fact be better suited to a text-based instructional strategy |

Recent advances in technology enable us to deliver courseware that is often highly graphical, in the sense that explanatory text may be limited, if not completely replaced by images (or pictorial representations). Consequently, this graphical delivery platform lends itself beautifully to the use of figurative representation. There is enough evidence from linguistics and psychology that people construe many concepts in terms of metaphor [10]. More research is needed to establish if, when and how, certain concepts are metaphorically represented [11].

2.1 Visual learning environment

In a recent debate on whether media has any influence on learning, [11] argued that traditional research fails to capture how various factors in the instructional setting interact, so as to affect the relationship between media and learning. According to [12], there is some evidence relating to how an individual's initial mental construct - or the representation in their mind of a perceivable concept example - might take the form of a graphical image. A visual language exists; individuals can, and often do, think visually; and they can and do learn visually; and they can and should express themselves visually [13]. Some people need help to develop cognitive skills, while others merely need help in increasing their elaborative skills [14]. With the advent of the graphical user interface (GUI) and computerized learning, we need to re-think our instructional strategies, to address the increased number of problems faced by learners and instructors alike [2]. Research towards a theory of visual learning is an exciting direction for educational psychology [15]. How do students process verbal and visual information, to build a mental model of the learning material [15]? There is little evidence in the literature, which makes a connection between learning abstract computer programming concepts and graphical representation. For instance: [16] developed a colour coding process (or tagging strategy) which a programming student can use to trace logic flow. This is a new visualization system that
A progression of instructional design, associates available technologies of the time with an instructional orientation [18]. A warning is therefore issued to instructional designers, to consider their position. These technological changes will force the focus of their strategies to shift, from the way instruction takes place - the actual mechanics - towards a learning environment that will be learner centred [18]. The Social Science Citation Index currently yields 228 World Wide Web entries; less than 20% of these articles describe an educational impact - instead they concentrate on usability issues. However, computer science research does make this connection between people and machinery (computer-human interaction). Unfortunately, according to [19], many of these articles describe generic instructional models, which are devoid of mechanisms to deal with matching individual intellectual skill and instructional format. This issue has been a tough cookie for researchers to crack, and the fortunes of learners continue to evade instructional science researchers. Questions relating to the interactive effects of cognitive style and instructional format on learning outcomes are still unanswered [11]. Further research is needed to explore mental models via instructional strategies appealing to visual or verbal cognitive processing [20].

2.2 Shifting paradigms of instructional design

A progression of instructional design, associates available technologies of the time with an instructional orientation [18]. A warning is therefore issued to instructional designers, to consider their position. These technological changes will force the focus of their strategies to shift, from the way instruction takes place - the actual mechanics - towards a learning environment that will be learner centred [18]. The Social Science Citation Index currently yields 228 World Wide Web entries; less than 20% of these articles describe an educational impact - instead they concentrate on usability issues. However, computer science research does make this connection between people and machinery (computer-human interaction). Unfortunately, according to [19], many of these articles describe generic instructional models, which are devoid of mechanisms to deal with matching individual intellectual skill and instructional format. This issue has been a tough cookie for researchers to crack, and the fortunes of learners continue to evade instructional science researchers. Questions relating to the interactive effects of cognitive style and instructional format on learning outcomes are still unanswered [11]. Further research is needed to explore mental models via instructional strategies appealing to visual or verbal cognitive processing [20].

2.3 Clarity of cognitive style

Cognitive styles are definitely still in, they may go in and out of fashion, however, and they will never cease to be important. "They show promise for helping psychologists understand some of the variation in school and job performance that cannot be accounted for by individual differences in abilities" [21:710]. Individual differences in preferred mental representations should be taken into account [22]. It appears to be a bit like leading a horse to water; even when a number of different instructional strategies are taught, students will still use the one that is easiest for them, according to [23]. Understanding the literature relating to individual learning attributes is quite a challenge. Terms describing how individuals process information change according to the researcher's paradigm. Early attempts during the 1950's and 1960's by psychologists researching cognitive abilities and processes, produced a fragmented list of models and labels derived mainly from single experiments [24]. They argue that cognitive style is understood to be an individual's preferred and habitual approach to organizing and representing information. [25] were able to condense the earlier style constructs into two families of cognitive style. Their Wholist:Analytic and Verbal:Imager cognitive continua reflect an integrative model of cognitive style. Moreover, [26] were able to identify a third group of models which lay outside of the earlier research on cognitive processes, which also became known as cognitive or learning styles. They point out that these models must coexist, should be called learning strategies.

There is a need to rationalise contemporary theory of learning styles [26]: "The term 'learning style' should be understood to refer to an individual set of differences that include not only a stated personal preference for instruction or an association with a particular form of learning activity but also individual differences found in intellectual or personal psychology" [24:51]. In other words, the term learning style describes the individual differences in the process-of-learning, which has a more external (or environmental) focus than the term cognitive style, which describes the information-processing-characteristics within an individual learner. Much of the earlier cognitive centred research focused on functioning (or mode of processing) which reflects their Wholist:Analytic dimension.

2.4 Differences in cognitive style

Researchers in general, have been aware of learners' cognitive differences and the implications for instructional design. For instance, [1] called for instructional designers to give consideration to learners' cognitive styles. Over a decade ago, [27] stated that instructional practitioners have been slow to respond to an increasing need to make their methods of instruction more effective, efficient, and appealing. While proposing their Concept Teaching Model, [28] also suggested there was a need for more research into the possible interactions between the instructional design variables and individual differences.

Getting to the crux of the problem is complex. Explaining the issues relating to how we think about things in everyday terms is difficult. The cerebral hemisphere researchers are now making headway. Recent work has widened the evidence for the science of instruction [20]. They were looking at the influence of an interactive multimedia (text and pictures) learning strategy (in the form of a physics tutor), and individual's cognitive differences. In the initial learning phase, which involved learning new concepts, they found that the right-hemisphere (used for intuition and global functioning) performed better than the left-hemisphere (used for linear, sequential, and logical functions). It appears that we can now say that parts of our mind work in a series of mutual cognitive effort. There are two distinct ways humans generate images according to [29]. First, the left hemisphere best handles categorical spatial relations (like recognising variance of things like on/off, left/right, and above/below concepts). While the second way humans generate images is to coordinate spatial relations (like picking out the embedded detail in things when judging distance between objects, or noticing when items have been shifted on a desk).
Measurement of an individual's relative right/left hemisphere performance and their cognitive style dominance, has been a target of researchers from several disciplines over the last decade. Assessing the position of an individual on two basic dimensions of cognitive style [25], uses their Cognitive Styles Analysis (CSA). This is a computerized testing program derived from a series of empirical studies carried out at Birmingham University, in the UK (for a full description of the CSA, see [24]). The first dimension (Verbal:Imagery), measures the way people prefer to represent information during thinking. The second dimension (Wholist:Analytic) measures people's mode of processing information. Riding proposed that the two cognitive styles may be thought of as orthogonal. This means that an individual's position on one dimension does not affect their position on the other. Riding explains that for instance, an individual may be a Wholist and an Imager (W:I), while another individual may be an Analytic and an Imager (A:I); someone else may be a Wholist and a Verbalizer (W:V), while another may be an Analytic and a Verbalizer (A:V). He draws on Pavio's [30] work which shows that some people think in terms of mental pictures (visualizers): while others think in terms of words (verbalizers). Riding points out that people are capable of utilising either cognitive mode, although some people have a tendency to use only one mode - visual or verbal. The dominant cognitive style affects performance in both the perceptual and conceptual domains of the learning process [31].

Surely it follows that a more effective instructional strategy would facilitate active integration of these cognitive styles.

2.5 Complementary CSA ratios

According to Riding, the Wholist:Verbalizers are likely to utilize their dominant style for verbal representation of information, having the characteristic of both semantic coding and a degree of analytic facility as well as having an ability to internally process what they see as imagery, which has both a pictorial quality and its associated wholeness. On the other hand, the Analytic:Verbalizer and Wholist:Imager combinations, are both less complementary, with the former having difficulty visualizing how facts and details fit into the bigger picture, and the latter unable to focus on detailed information.

3. Research Experiments

Three separate experiments were conducted that extend the Riding research: two pilot studies and a final experiment [8, 9]. A total of 264 undergraduate students participated in the study. It is important to note that in all three experiments, the measuring of cognitive style was carried out prior to any other data gathering. The CSA provided a convenient yet scientifically robust means to operationalize participants' cognitive style. The CSA-ratio was one of the independent research variables, while the second was instructional format.

Figure:1 Graphical Metaphor

Each experiment had two instructional treatments; text-only (Treatment-1) and text-plus-graphics (Treatment-2), which included graphical metaphors to represent the concept of computer-programming loops (Figure:1). The activity of dual coding [30] of facts (as conducted in Treatment-2) provided a multi-sensory instructional approach [32]. They argue this cognitive process may maximize the skills a student brings to the learning session, while minimizing the experiences where a student's ineptitudes are stressed.

3.1 Measuring cognitive skills performance

In order to evaluate the cognitive performance of each participant, the QUEST Interactive Test Analysis System was used. This test measurement application allows for improved analyses of an individual's performance relative to other participants, and relative to the test-item difficulty or programming knowledge levels. QUEST establishes a model, which allows the best estimate of the probability of an individual making a certain response to a test-item. In addition, it estimates test-item characteristics. For a full description of QUEST and its capabilities see [33, 34].
3.2 Assessment of cognitive skills

The classical approach to assessment identifies test-items which do not distinguish between high and low scores, whereas QUEST relies on a type of assessment that is similar to a criterion measure. This means an observation is "directly compared to a single, fixed level of performance, or pre-specified criterion, and is interpreted as either mastery or non-mastery" [35:264]. It is now possible to look at a QUEST Variable Map to determine the behaviour of test-items and participants (or cases) compared to each other.

3.3 Scaling the performance

Item Response Theory describes the assessment method used by QUEST. It compares actual patterns of responses from the interactions of test-items with participants compared with a model pattern. This becomes the fit-statistic. Unusual patterns can be investigated. Central to QUEST is the measurement model developed in 1960 by a Danish statistician called Georg Rasch [36]. QUEST develops a unidimensional scale with equal intervals along each axis, to measure individuals' performance and test-items together (Figure:2). This scaling feature enables a developmental sequence of learning tasks to be arranged from simple to more complex. It is also possible to locate an individual at different skill levels along this scale. The assessment of particular skill levels, relies on choosing tasks that can provide evidence which effectively distinguishes between those who have the required knowledge and those who have not.

Figure:2 QUEST Variable Map

4. Results

Coding participants by instructional treatment sub-grouping (ie: Imager with the text-plus-graphical metaphor) one can analyze which treatment sub-group performed best. A brief summary of the final experiment's results is next; it will be structured by a description of the performance of the Riding single-category-of-cognitive-style (SCCS) groups, and then the integrated-cognitive-style (ICS) sub-groups. Measurement of cognitive performance was taken from their QUEST logit value (Qlv) defined as the difference between their pretest and post-test performances, expressed below as a QUEST difference logit value (Qdlv). A statistical means analysis was conducted, measuring effect size (ES) between two treatment groups or sub-groups [37]. \[ ES = \frac{|Ma-Mb|}{SD} \] where the nominator is the absolute value of the difference between the mean-Qlv of the first sample group (Ma) and the second sample group (Mb), and the denominator is the combined standard deviation of the two groups (Sd).

The null hypothesis being tested was:

that the combination of cognitive style and/or instructional treatment will have no affect on cognitive performance
4.1 SCCS groups

These groups consisted of the two cognitive style continua (Verbal:Imagery; Wholist:Analytic) \[4\] split into halves, firstly into Wholists and Analytics, and then into Verbalizers and Imagers (Figure:3). A brief description of their performance follows:

**Wholists** - clearly performed better with Treatment-2 than Treatment-1. Their Treatment-2 Qdlv of 0.225 is the highest Qlv of all the SCCS groups and is 0.146 logits higher than their Treatment-1 counterparts. This results in an ES of 0.222 and a 40% probability that the instructional treatment affected performance.

**Analytics** - also performed best with the graphical metaphor instructional treatment (Treatment-2), with a 0.803 logit higher mean Qdlv than the Treatment-1 group. The latter group actually performed worse on the post-test than the pretest, relative to the other groupings, with a Qdlv of -0.054. However, the ES (0.096) is negligible indicating that treatment type had little effect on the Analytics’ performance.

**Verbalizers** - this group perform better with Treatment-2 than Treatment-1. The Verbalizer:Treatment-2 mean Qdlv is 0.137 higher, and their post-test median and spread are higher than their Treatment-1 counterparts.

**Imagers** - this group given Treatment-2 performed slightly better than their Treatment-1 counterparts, with a higher mean Qdlv of 0.009 compared to -0.040. The ES of 0.061 is negligible. Neither Imager group has performed well, relative to the other SCCS groups.

4.2 ICS Sub-groups

The ICS sub-groups integrate the two cognitive style dimensions, splitting the sample into four sub-groups (Figure:3) (Wholist:Verbalizer, Analytic:Verbalizer, Wholist:Imager, and Analytic:Imager) \[4\]. A brief description of sub-group performance follows:

**Wholist:Verbalizer** - given Treatment-2, obtained a higher mean-Qdlv (0.155) than their Treatment-1 counterparts (0.073). The resulting ES of 0.130 is small to negligible.

**Analytic:Verbalizer** - also scored higher with Treatment-2 (mean-Qdlv = 0.235) than their Treatment-1 counterparts (mean-Qdlv = 0.055). The ES of 0.220 for Treatment-2 sub-group reflects the higher post-test median and a narrower distribution than their Treatment-1 counterparts.

**Wholist:Imager** - clearly scored higher with Treatment-2. Their mean-Qdlv of 0.312 is 0.227 logits higher than their Treatment-1 counterparts resulting in a median ES of 0.330. Given the sample size, there is a 45% chance that the instructional treatment affected cognitive performance.

**Analytic:Imager** - neither of the Analytic-Imager sub-groups scored well on the experiment. The text-only (Treatment-1) sub-group obtained a mean-Qdlv of -0.118, scoring a lower logit value on the post-test, than the pretest. However, the Treatment-2 sub-group scored even lower with a mean-Qdlv of -0.175 logits. The ES of 0.066, is negligible.

**Figure:3 Cognitive Performance Comparison**

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<td><strong>Imagers</strong>:T2</td>
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4.3 Interactive affect of cognitive style and instruction

The previous two sub-sections have compared the logit values of each SCCS group or ICS sub-group, with their counterparts, given the opposite instructional treatment. However, Figure 3 clearly shows that much more variation occurs between the cognitive style groups/sub-groups than within. For instance: the ES between the Wholist-Imager: Treatment-2 sub-group and the Analytic-Imager: Treatment-2 sub-group is a large 0.580. Similarly, a comparison of the former sub-group with the Analytic-Imager: Treatment-1 sub-group yields an ES of 0.566. This indicates an over 75% probability that the interaction of cognitive style and instructional treatment had an effect on the acquisition of abstract programming knowledge performance. The ES was over 0.3 for the majority of comparisons.

5. Discussion

The purpose of this experiment was to explore the relationship of instructional format with cognitive style. Due to the complexities of this relationship many researchers have chosen to measure the effect of each variable separately. For example, [20] were only commenting on instructional format when they found that the best learning performance occurred when the concepts were given with less abstract material, and presented early in each instructional segment.

Technology is driving courseware designers towards the World Wide Web (www) where economies of scale are apparent. This rush to the www pushes the inquiry for visual learning to the top of the think-tank. Consequently researchers are now turning to look at work which involves cerebral hemispheres for some answers. We can no longer afford to take for granted that students will learn by default. There have been a number of calls for more research to explore the relationship between instructional strategies via visual learning platforms, and cognitive processing [11, 20, 38]. For instance, there is increased interest in the visual representation of computer programming. Results from investigations into how a program is represented may demonstrate this aspect in a dramatic way.

Based on the findings of this research, new questions must be explored:

why do the Analytic-Imagers respond better to the text-only instructional format, when learning programming concepts?

Furthermore, comparing the Verbalizers and Imagers:

why are the Verbalizers able to function better without the written description of the new abstract concepts to be learned?

The McKay research separated the delivery medium and instructional method as described by [41, 42]. By doing this, Clark argued that it is possible to not only identify particular cognitive processes or strategies that are necessary for learning, but that these strategies can leverage students who cannot, or will not provide for themselves. Previous research confounds the two constructs of media and method [42]. Unlike the criticism from [43], that we test treatments on unsuspecting and often unwilling subjects; the instructional treatments for the McKay research were tested on voluntary subjects, who were fully aware of the experiment's purpose. Furthermore, the results showed they were interested in the learning material (programming concepts). These concepts (embedded within the instructional treatment) were later used by the participants to facilitate their knowledge-construction when developing a functional end-user database system.
The findings from these experiments will be used to develop a computerized instructional learning shell that will cater for individual cognitive style. The instruction will commence with a networked version of the CSA [44]. Once the learner's cognitive style has been identified, the computer will recommend the instructional format which best suits that cognitive style (Figure:4).

Figure:4 Computerized Learning Shell

This research reopens the need to concentrate on the relationship between learning task and cognitive style. The three experiments clearly show an interactive effect between cognitive style and instructional format. However, the observed interaction is not as simple as some previous researchers have proposed. Unlocking some of these mysteries will enable training material developers to accurately target their learners.

Acknowledgement

The authors wish to thank Dr Rodney Earle (Brigham Young University) and Keven Asquith for their patient and careful reading of the early drafts of this paper.

References

[18] Cooper, P.A. Paradigm shifts in designed instruction: From behaviorism to cognitivism to constructivism. Educational
Appendix Item No:1 Invited Conference Paper


Appendix Item No:2  Marking Scheme

(Refer to Chapter Five : Research Methodology and Experimental Design, page 179)
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Appendix Item No:3
Programming Knowledge Performance Bands (pkpb's)

(Refer to Chapter Six : Results)

Data Tables for Histograms (See pages 225 and 238)

Table:1  Relative Movement Between pkpb's From Pre to Post-Test (SCCS)
Table:2  Relative Movement Between pkpb's From Pre to Post-Test (ICS)
Table:3 Relative Movement Between pkpb's - Pre to Post-Test for Males SCCS
Table:4 Relative Movement Between pkpb's - Pre to Post-Test for Female SCCS
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<tr>
<td>T2: % of group in pkpb</td>
<td>3.57% -17.86% 10.71% -3.57% -3.57% 7.14% 0.00% 3.57%</td>
<td>3.57% -17.86% 10.71% -3.57% -3.57% 7.14% 0.00% 3.57%</td>
</tr>
</tbody>
</table>

Table 2: Relative Movement Between pkpb’s From Pre to Post-Test (UCS Subset)
<table>
<thead>
<tr>
<th>Diff (Post-Pre)</th>
<th>Males</th>
<th>Wholists</th>
</tr>
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<tbody>
<tr>
<td>T1: # of cases in pkpb</td>
<td>18</td>
<td>0</td>
</tr>
<tr>
<td>T1: % of group in pkpb</td>
<td>0.00%</td>
<td>-11.11%</td>
</tr>
<tr>
<td>T2: # of cases in pkpb</td>
<td>24</td>
<td>1</td>
</tr>
<tr>
<td>T2: % of group in pkpb</td>
<td>4.17%</td>
<td>-8.33%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Diff (Post-Pre)</th>
<th>cases</th>
<th>Analytics</th>
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</thead>
<tbody>
<tr>
<td>T1: # of cases in pkpb</td>
<td>27</td>
<td>1</td>
</tr>
<tr>
<td>T1: % of group in pkpb</td>
<td>3.70%</td>
<td>-7.41%</td>
</tr>
<tr>
<td>T2: # of cases in pkpb</td>
<td>29</td>
<td>1</td>
</tr>
<tr>
<td>T2: % of group in Qpb</td>
<td>3.45%</td>
<td>-3.45%</td>
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<table>
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<tr>
<th>Diff (Post-Pre)</th>
<th>cases</th>
<th>Verbalisers</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1: # of cases in pkpb</td>
<td>18</td>
<td>1</td>
</tr>
<tr>
<td>T1: % of group in pkpb</td>
<td>5.56%</td>
<td>-5.56%</td>
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<tr>
<td>T2: # of cases in pkpb</td>
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<td>1</td>
</tr>
<tr>
<td>T2: % of group in pkpb</td>
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<td>-4.17%</td>
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<table>
<thead>
<tr>
<th>Diff (Post-Pre)</th>
<th>cases</th>
<th>Imagers</th>
</tr>
</thead>
<tbody>
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<td>T1: # of cases in pkpb</td>
<td>27</td>
<td>0</td>
</tr>
<tr>
<td>T1: % of group in pkpb</td>
<td>0.00%</td>
<td>-11.11%</td>
</tr>
<tr>
<td>T2: # of cases in pkpb</td>
<td>29</td>
<td>1</td>
</tr>
<tr>
<td>T2: % of group in pkpb</td>
<td>3.45%</td>
<td>-6.90%</td>
</tr>
</tbody>
</table>

| Prog. Knowl. Perf. B pkpb | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 |
| Diff (Post-Pre) | Females | cases | Wholists |  |
|----------------|---------|-------|----------|
| T1: # of cases in pkpb | 24 | 0 | 1 | -2 | 4 | -1 | 0 | -2 | 0 |
| T1: % of group in pkpb | 0.00% | 4.17% | -8.33% | 16.67% | -4.17% | 0.00% | -8.33% | 0.00% |
| T2: # of cases in pkpb | 14 | 0 | 1 | 0 | 1 | -1 | 0 | -2 | 1 |
| T2: % of group in pkpb | 0.00% | 7.14% | 0.00% | 7.14% | -7.14% | 0.00% | -14.29% | 7.14% |

| Diff (Post-Pre) | cases | Analytics |  |
|----------------|-------|-----------|
| T1: # of cases in pkpb | 32 | -1 | 1 | -3 | -2 | 4 | 2 | -1 | 0 |
| T1: % of group in pkpb | -3.13% | 3.13% | -9.38% | -6.25% | 12.50% | 6.25% | -3.13% | 0.00% |
| T2: # of cases in pkpb | 26 | 0 | 0 | 2 | -3 | 0 | 1 | 1 | -1 |
| T2: % of group in Qpb | 0.00% | 0.00% | 7.69% | -11.54% | 0.00% | 3.85% | 3.85% | -3.85% |

| Diff (Post-Pre) | cases | Verbalisers |  |
|----------------|-------|-------------|
| T1: # of cases in pkpb | 23 | 0 | 0 | -2 | 0 | 4 | 2 | -1 | 0 |
| T1: % of group in pkpb | 0.00% | 0.00% | -8.70% | 0.00% | 17.39% | 8.70% | -17.39% | 0.00% |
| T2: # of cases in pkpb | 24 | 0 | 3 | 1 | -3 | -2 | 1 | 0 | 0 |
| T2: % of group in pkpb | 0.00% | 12.50% | 4.17% | -12.50% | -8.33% | 4.17% | 0.00% | 0.00% |

| Diff (Post-Pre) | cases | Imagers |  |
|----------------|-------|---------|
| T1: # of cases in pkpb | 33 | -1 | 2 | -3 | 2 | -1 | 0 | 1 | 0 |
| T1: % of group in pkpb | -3.03% | 6.06% | -9.09% | 6.06% | -3.03% | 0.00% | 3.03% | 0.00% |
| T2: # of cases in pkpb | 16 | 0 | -2 | 1 | 1 | 1 | 0 | -1 | 0 |
| T2: % of group in pkpb | 0.00% | -12.50% | 6.25% | 6.25% | 6.25% | 0.00% | -6.25% | 0.00% |

| Prog. Knowl. Perf. B pkpb | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 |
These results incorporate the Rasch statistics summary; including:

Mean, SD, SD (adjusted), Reliability of estimate, and Fit statistics
### Item Analysis Results for Observed Responses

**9/7/98 12:53 all on all (N = 195 L = 40 Probability Level= .50)**

<table>
<thead>
<tr>
<th>Item</th>
<th>Infit MNSQ</th>
<th>Disc</th>
</tr>
</thead>
<tbody>
<tr>
<td>1: pre1</td>
<td>1.03</td>
<td>.15</td>
</tr>
<tr>
<td>2: pre2</td>
<td>1.13</td>
<td>-.03</td>
</tr>
<tr>
<td>3: pre3</td>
<td>1.00</td>
<td>.25</td>
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<tr>
<td>4: pre4</td>
<td>1.10</td>
<td>.35</td>
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**Item 1: pre1**

- **Categories:** 0, 1, 2, 3, 4, missing
- **Count:** 66, 129, 0, 0, 0, 0
- **Percent (%):** 33.8, 66.2, .0, .0, .0
- **Pt-Biserial:** -.15, .15
- **p-value:** .018, .018
- **Mean Ability:** -1.02, -.83
- **Step Labels:** 1
- **Thresholds:** 1
- **Error:** .00

**Item 2: pre2**

- **Categories:** 0, 1, 2, 3, 4, missing
- **Count:** 68, 127, 0, 0, 0, 0
- **Percent (%):** 34.9, 65.1, .0, .0, .0
- **Pt-Biserial:** .03, -.03
- **p-value:** .356, .356
- **Mean Ability:** -.88, -.90
- **Step Labels:** 1
- **Thresholds:** 1
- **Error:** .00

**Item 3: pre3**

- **Categories:** 0, 1, 2, 3, 4, missing
- **Count:** 112, 83, 0, 0, 0, 0
- **Percent (%):** 57.4, 42.6, .0, .0, .0
- **Pt-Biserial:** -.25, .25
- **p-value:** .000, .000
- **Mean Ability:** -1.00, -.75
- **Step Labels:** 1
- **Thresholds:** 1
- **Error:** .00

**Item 4: pre4**

- **Categories:** 0, 1, 2, 3, 4, missing
- **Count:** 100, 60, 2, 33, 0, 0
- **Percent (%):** 51.3, 30.8, 1.0, 16.9, .0
- **Pt-Biserial:** -.31, .11, .01, .28
- **p-value:** .000, .068, .446, .000
- **Mean Ability:** -1.05, -.81, -.83, -.56
- **Step Labels:** 1, 2, 3
- **Thresholds:** 1, 2, 3
- **Error:** .00, .00, .00
### Appendix Item No:4

#### QUEST Interactive Test Analysis System : Test-Item Analysis Results

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<tr>
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<td>41</td>
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<tr>
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## Appendix Item No: 4

### QUEST Interactive Test Analysis System: Test-Item Analysis Results

<table>
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<th>Step Labels</th>
<th>Thresholds</th>
<th>Error</th>
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<tbody>
<tr>
<td>9: pre9</td>
<td>0 1 2 3 4 missing</td>
<td>15 50 94 34 2 0</td>
<td>7.7 25.6 48.2 17.4 1.0</td>
<td>-.25 -.03 -.18 .318 .190 .097 .021</td>
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<td>1 2 3 4</td>
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<td>11: pr11</td>
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### Item 15: pr15

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<th>Error</th>
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<td>Disc</td>
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<td>Count</td>
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## Appendix Item No: 4

### QUEST Interactive Test Analysis System: Test-Item Analysis Results

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<td>-.08</td>
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### Appendix Item No:4
#### QUEST Interactive Test Analysis System : Test-Item Analysis Results

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<th>Mean Ability</th>
<th>Step Labels</th>
<th>Thresholds</th>
<th>Error</th>
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<td>.008 .008 NA NA NA</td>
<td>-.98 -.80 NA NA NA</td>
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<tr>
<td>26</td>
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<td>-.42 .01 .18 .31 NA</td>
<td>.000 .424 .007 .000 NA</td>
<td>-1.18 -.87 -.73 -.56 NA NA</td>
<td>1 2 3</td>
<td></td>
<td></td>
</tr>
<tr>
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<td>-.96 -.83 NA NA NA NA</td>
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<td>-.30 .00 .27 NA NA</td>
<td>.000 .500 .000 NA NA NA</td>
<td>-1.15 -.89 -.75 NA NA NA</td>
<td>1 2</td>
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### Appendix Item No:4

**QUEST Interactive Test Analysis System : Test-Item Analysis Results**

#### Item 29: 9p13

- **Infit MNSQ =** 0.95  
- **Disc =** 0.12

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**Step Labels:** 1

**Thresholds:** 1.97

**Error:** 0.00

---

#### Item 30: PO10

- **Infit MNSQ =** 1.06  
- **Disc =** 0.26

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<tbody>
<tr>
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</tr>
<tr>
<td>Percent (%)</td>
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<td>16.4</td>
<td>10.3</td>
<td>3.6</td>
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<td>.20</td>
<td>.07</td>
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**Step Labels:** 1, 2, 3

**Thresholds:** -.28, .17, .97

**Error:** 0.00

---

#### Item 31: PO11

- **Infit MNSQ =** 0.93  
- **Disc =** 0.36

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**Step Labels:** 1

**Thresholds:** -1.53

**Error:** 0.00

---

#### Item 32: 1210

- **Infit MNSQ =** 0.95  
- **Disc =** 0.33

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**Step Labels:** 1

**Thresholds:** -1.30

**Error:** 0.00
### QUEST Interactive Test Analysis System: Test-Item Analysis Results

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**Appendix Item No:4**

**QUEST Interactive Test Analysis System : Test-Item Analysis Results**

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<th>Mean Ability</th>
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### Quest Interactive Test Analysis System: Test-Item Analysis Results

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<th>Percent (%)</th>
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<th>p-value</th>
<th>Mean Ability</th>
<th>Step Labels</th>
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The individual item statistics are calculated using all available data. The overall mean, standard deviation and internal consistency indices assume that missing responses are incorrect. They should only be considered useful when there is a limited amount of missing data.
Appendix Item No:5

QUEST : Participant(Case) : Statistical Estimates

(Refer Chapter Six : Results)
### Case Estimates

**all on all (N = 195 L = 40 Probability Level= .50)**

#### Summary of case Estimates

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#### Fit Statistics

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0 cases with zero scores
0 cases with perfect scores

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### Case Estimates

**all on pre (N = 195 L = 20 Probability Level= .50)**

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1 cases with zero scores
0 cases with perfect scores

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### Case Estimates

**all on post (N = 195 L = 20 Probability Level= .50)**

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0 cases with zero scores
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### Case Estimates

**t2wv on all (N = 22 L = 40 Probability Level= .50)**

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0 cases with zero scores
0 cases with perfect scores

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### Case Estimates

**t2wv on pre (N = 22 L = 20 Probability Level= .50)**

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0 cases with zero scores
0 cases with perfect scores

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### Case Estimates

**t2wv on post (N = 22 L = 20 Probability Level= .50)**

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0 cases with zero scores
0 cases with perfect scores
Appendix Item No: 5

QUEST : Participant (Case) : Statistical Estimates

:studyctl.ctl: GROUP: T1WI : RUN1 : ANCHOR ON

Case Estimates 12/ 7/98 12: 7

t1wi on all (N = 23 L = 40 Probability Level= .50)

Summary of case Estimates

Mean -.73
SD .44
SD (adjusted) .36
Reliability of estimate .69

Fit Statistics

Infit Mean Square Outfit Mean Square
Mean 1.15 Mean 49.80
SD .37 SD 72.36

Infit t Outfit t
Mean .44 Mean 3.47
SD 1.25 SD 3.11
0 cases with zero scores
0 cases with perfect scores

Case Estimates 12/ 7/98 12: 7

t1wi on pre (N = 23 L = 20 Probability Level= .50)

Summary of case Estimates

Mean -.60
SD .68
SD (adjusted) .44
Reliability of estimate .42

Fit Statistics

Infit Mean Square Outfit Mean Square
Mean 1.55 Mean 67.02
SD .79 SD 123.28

Infit t Outfit t
Mean 1.02 Mean 3.28
SD 1.32 SD 1.98
0 cases with zero scores
0 cases with perfect scores

Case Estimates 12/ 7/98 12: 7

t1wi on post (N = 23 L = 20 Probability Level= .50)

Summary of case Estimates

Mean -.81
SD .49
SD (adjusted) .39
Reliability of estimate .64

Fit Statistics

Infit Mean Square Outfit Mean Square
Mean .94 Mean .99
SD .35 SD .39

Infit t Outfit t
Mean -.12 Mean .00
SD .98 SD .89
0 cases with zero scores
0 cases with perfect scores

:studyctl.ctl: GROUP: T1WI : RUN1 : ANCHOR ON

Case Estimates 12/ 7/98 12: 7

t1wi on post (N = 23 L = 20 Probability Level= .50)

Summary of case Estimates

Mean -.81
SD .49
SD (adjusted) .39
Reliability of estimate .64

Fit Statistics

Infit Mean Square Outfit Mean Square
Mean .94 Mean .99
SD .35 SD .39

Infit t Outfit t
Mean -.12 Mean .00
SD .98 SD .89
0 cases with zero scores
0 cases with perfect scores

:studyctl.ctl: GROUP: T1WI : RUN1 : ANCHOR ON

Case Estimates 12/ 7/98 12: 7

t1wi on all (N = 23 L = 40 Probability Level= .50)

Summary of case Estimates

Mean -.73
SD .44
SD (adjusted) .36
Reliability of estimate .69

Fit Statistics

Infit Mean Square Outfit Mean Square
Mean 1.15 Mean 49.80
SD .37 SD 72.36

Infit t Outfit t
Mean .44 Mean 3.47
SD 1.25 SD 3.11
0 cases with zero scores
0 cases with perfect scores
### Appendix Item No:5

**QUEST : Participant(Case) : Statistical Estimates**

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0 cases with zero scores
0 cases with perfect scores

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0 cases with zero scores
0 cases with perfect scores

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### Case Estimates

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#### Summary of case Estimates

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0 cases with zero scores
0 cases with perfect scores

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### Case Estimates

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0 cases with zero scores
0 cases with perfect scores
Appendix Item No:5

QUEST : Participant(Case) : Statistical Estimates

:studyctl.ctl: GROUP: T2AV : RUN1 : ANCHOR ON

Case Estimates 12/ 7/98 15:21
t2av on all (N = 27 L = 40 Probability Level= .50)

Summary of case Estimates

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Fit Statistics

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0 cases with zero scores

0 cases with perfect scores

Case Estimates 12/ 7/98 15:21
t2av on pre (N = 27 L = 20 Probability Level= .50)

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Fit Statistics

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Infit t  Outfit t

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1 cases with zero scores

0 cases with perfect scores

Case Estimates 12/ 7/98 15:21
t2av on post (N = 27 L = 20 Probability Level= .50)

Summary of case Estimates

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Fit Statistics

Infit Mean Square  Outfit Mean Square

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Infit t  Outfit t

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0 cases with zero scores

0 cases with perfect scores
Appendix Item No:5

QUEST: Participant (Case): Statistical Estimates

:studyctl.ctl: GROUP: T1AI : RUN1 : ANCHOR ON

Case Estimates 12/7/98 13:30
t1ai on all (N = 37 L = 40 Probability Level= .50)
Summary of case Estimates

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Fit Statistics

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Infit t

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0 cases with zero scores
0 cases with perfect scores

=====================================================================================
Appendix Item No: 5

QUEST : Participant (Case) : Statistical Estimates

:studyctl.ctl:    GROUP: T2AI : RUN1 : ANCHOR ON

Case Estimates 12/ 7/98 16:58

t2ai on all (N = 28 L = 40 Probability Level= .50)

Summary of case Estimates

Mean -.77
SD .69
SD (adjusted) .64
Reliability of estimate .86

Fit Statistics

Infit Mean Square Outfit Mean Square
Mean 1.26 Mean 62.05
SD .48 SD 181.56

Infit t Outfit t
Mean .64 Mean 2.75
SD 1.35 SD 2.58

0 cases with zero scores
0 cases with perfect scores

Case Estimates 12/ 7/98 16:58

t2ai on pre (N = 28 L = 20 Probability Level= .50)

Summary of case Estimates

Mean -.44
SD .93
SD (adjusted) .78
Reliability of estimate .70

Fit Statistics

Infit Mean Square Outfit Mean Square
Mean 1.60 Mean 27.45
SD .89 SD 59.60

Infit t Outfit t
Mean .85 Mean 2.77
SD 1.18 SD 1.74

0 cases with zero scores
0 cases with perfect scores

Case Estimates 12/ 7/98 16:58

t2ai on post (N = 28 L = 20 Probability Level= .50)

Summary of case Estimates

Mean -.98
SD .86
SD (adjusted) .77
Reliability of estimate .81

Fit Statistics

Infit Mean Square Outfit Mean Square
Mean .98 Mean 1.11
SD .37 SD .65

Infit t Outfit t
Mean -.14 Mean .22
SD 1.04 SD .94

0 cases with zero scores
0 cases with perfect scores
Appendix Item No:6
QUEST : Participant(Case) Estimates : Estimate Order (All on All)

(Refer to Chapter Six : Results, page 228)
### NAME | SCORE MAXSCR | ESTIMATE | ERROR | INFIT | OUTFT | INFIT | OUTFT
--- | --- | --- | --- | --- | --- | --- | ---
181 1117MAI | 51 73 | -1.24 | .74 | .68
115 0807FAI | 44 73 | -1.24 | 1.44 | 1.08
170 1104MAI | 44 73 | -1.24 | .63 | -.13 | -.96
57 0405FWM | 43 73 | 1.00 | .11 | 1.18
29 0212MAV | 42 73 | -.50 | -.58 | -.73
62 0412FAI | 41 73 | .69 | -.01 | -.17
173 1107FWI | 41 73 | .23 | .25 | .26
17 0119FWI | 41 73 | -.23 | .67 | 1.42
191 1208FVI | 41 73 | .23 | -.15 | -.79
145 0915FVI | 38 73 | 1.36 | 1.18
154 1007MWV | 38 73 | 1.25 | -.40
20 0202FAV | 38 73 | .77 | -.71 | -.92
152 1005MFW | 38 73 | .75 | -.80 | -.16
71 0509MAV | 38 73 | 1.95 | 1.86
151 0914FAV | 37 73 | -.59 | -.62 | -.77
68 0503FWI | 37 73 | .89 | -.01 | .01
114 0805MAI | 37 73 | .98 | .02 | -.46
95 0617MAV | 37 73 | 1.01 | .33
155 1015FVI | 37 73 | .81 | -.57 | -.74
195 1212FVW | 37 73 | 1.21 | -.20
73 0511MAI | 37 73 | 1.32 | 1.08 | -.13
122 0814FVI | 37 73 | 1.70 | 2.03 | .77
153 1006FVI | 36 73 | 1.12 | -.08
74 0312MAV | 36 73 | 1.07 | 1.77 | 1.97
121 0813MAV | 36 73 | 1.74 | -.36
133 0905MAI | 36 73 | 1.10 | -.34 | .36
77 0515FVI | 36 73 | .72 | -.98 | -.96
143 0915MAI | 35 73 | .90 | -.71 | -.71
14 1104MAI | 35 73 | 1.62 | -.43 | -.76
61 0411MAV | 35 73 | .97 | -.12 | .12
148 1001MWV | 35 73 | .74 | -.89 | .86
10 0111FAI | 35 73 | 1.05 | .28 | -.32
49 0314FVI | 34 73 | .65 | .90 | -.93
23 0403FWM | 33 73 | 1.84 | .08 | .86
101 0706MAV | 34 73 | .81 | -.63 | .86
3 0103FAV | 34 73 | .84 | -.49 | .64
88 0609FWM | 34 73 | 1.52 | 1.69 | 3.08
182 1118MAI | 34 73 | .50 | -2.10 | -1.00
134 1022FWI | 34 73 | .97 | -.14 | .74
163 1016FWV | 34 73 | .84 | -.51 | -.70
165 1018FWV | 33 73 | .96 | -.04 | -.27
145 0917FWV | 33 73 | .81 | -.63 | -.72
1 0101MAI | 33 73 | .72 | -.93 | -.93
134 1104MAI | 33 73 | 1.30 | .43 | .90
174 1109MAV | 33 73 | .99 | .05 | -.34
108 0715FVW | 33 73 | 1.20 | .76 | 1.56
120 0812FWW | 33 73 | 1.19 | .76 | .44
44 0309MAI | 32 73 | .80 | -.71 | -.02
190 1207FWM | 32 73 | 1.34 | 1.20 | 1.56
63 0413FAV | 32 73 | .65 | 1.37 | -.91
19 0201FVI | 32 73 | 1.27 | 1.01 | 1.45
136 0908FWI | 32 73 | .81 | -.65 | -.10
124 0816MAI | 31 73 | .85 | -.50 | -.48
19 0212MAI | 31 73 | 1.33 | 1.32 | -1.04
164 1017FWI | 31 73 | .80 | -1.53 | -.53
31 0215FVW | 31 73 | .58 | 1.77 | .61
38 0303MWI | 31 73 | 1.34 | 1.23 | .07
150 1003FWM | 31 73 | .78 | -.79 | -.49
149 1002MFW | 31 73 | .95 | -.09 | .03
83 0604FVW | 30 73 | .84 | -.54 | .10
112 0803MFW | 30 73 | 1.09 | 1.41 | .21
180 1106FAL | 30 73 | .11 | .68 | -.38
107 0714FVI | 30 73 | 1.33 | 1.22 | .69
169 1107FVW | 29 73 | .78 | -1.04 | -.35
53 0318FWV | 29 73 | .56 | -.94 | -.62
104 0711MAI | 29 73 | 1.62 | 2.06 | 1.61
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Case Estimates In estimate Order 9/ 7/98 17:23

:studyctl.ctl: OVERALL PERFORMANCE RUN2 : ANCHOR ON

Appendix Item No:6

QUEST : Participant(Case) Estimates : Estimate Order (All on All)
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3. Appendix Item No:6

QUEST: Participant (Case) Estimates: Estimate Order (All on All)
Appendix Item No:7 : Cohen’s Statistical Power Table No:2.3.2 : Power of t test of $m_1 = m_2$ at $a_1 = .05$

(Refer to Chapter Six : Results, page 206)
### Appendix Item No:7  : Cohen's Statistical Power Table No:2.3.2  : Power of t test of $m_1 = m_2$ at $a_1 = .05$

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* Power values below this point are greater than .995