CHAPTER 3

THE USE OF COGNITIVE STYLES FOR PERSONALISING THE INTERFACE OF WEB-BASED LEARNING MATERIALS

3.1 INTRODUCTION

In Chapter 2 it was argued that current requirements of the education sector are driving the development and integration of LT, and particularly of Web-based learning, towards a learner-centred model. Also, that this move is in line with leading approaches to teaching and learning, in which knowledge is individually constructed. In turn, this seems to suggest that effectively supporting the learner in the construction of knowledge through the use of LT depends on the ability of such technology to tailor instruction to the needs of individuals [Wiley, 2003]. Examples of this approach are the several AH systems that have been introduced over the past years, which are capable of adapting their functionality to new conditions, usually defined from a series of underlying models [Brusilovsky 1996, 2001].

Some selected AH systems were analysed and the issue of individual differences identified as one still challenging research in the field. It was suggested that in order to progress personalisation, further work is required investigating the relationship between individual differences and interface settings [Brusilovsky, 2001]. Among the wide range of individual differences, cognitive styles were put forward as a potentially useful source to inform interface design since they are considered to be the stable approach of each learner to knowledge acquisition and can be described in terms of a manageable number of dimensions.

For the purposes of the research, the methodology suggested by some authors [Benyon, 1993; Cristea & De Bra, 2002] for dealing with cognitive differences was adopted. It firstly required assessing the extent of the differences in order to identify what to measure and how to measure it. Once differences were identified, their essential characteristics were selected and extracted, taking into account features of the interaction, features of the users, and stability of the features. The key characteristics identified were then used to outline an approach to the design of adaptive interfaces for Web-based learning materials. In this chapter, this research strategy is detailed including the design approach derived; the LEARNINT prototype, developed on the basis of such a design framework, is also presented.

3.2 COGNITIVE STYLES AND LEARNING STYLES

Researchers in the field of individual differences have used the word *style* to refer to "a set of individual qualities, activities or behaviour sustained over a period of time, possibly reflecting a basic human need to create a sense of identity, which is after all, the essence of individuality" [Riding & Rayner, 1998; p. 5].

In the context of Web-based learning the importance of an awareness of style is its potential for improving attention to diversity and enhancing the students' learning experience and performance.

To assess the extent of cognitive differences, concepts related to cognitive styles and learning styles are analysed in this section and their relevance for the interface design of Web-based learning materials discussed.

3.2.1 Defining Cognitive Style and Learning Style

Over the years, many authors [Schmeck, 1988; Entwistle, 1988, 1988b; Benyon, 1993; Atkinson, 2001; Webster, 2001; Cristea & De Bra, 2002; Laurillard, 2002] have explored the relevance of cognitive styles and learning styles for student learning. Although the terms have been used interchangeably, learning styles can be considered as characteristic cognitive, affective and psychological behaviours that serve as indicators of how learners perceive, interact and respond to learning. Learning styles can vary for the individual when taking into account the vast range of internal and external factors that influence motivation and learning in a given situation, such as curriculum, mode of assessment or amount of time available [Kolb, 1984; Schmeck, 1988; Benyon, 1993; Webster, 2001; Cristea & De Bra, 2002]. There are some authors [Entwistle, 1988; Ramsden, 1988] that prefer the label *orientation* when referring to an individual's consistent approach to learning.

Cognitive styles, on the other hand, are considered more fundamental to the individual's personal and psychological makeup, "an individual's preferred and habitual approach to organising and representing information" [Riding & Rayner, 1998, p. 8]. Thus cognitive style is considered to be the specific stable approach of each learner to knowledge acquisition, a fixed characteristic of an individual, and one that is mainly independent of intelligence [Entwistle, 1988; Ramsden, 1988; Benyon, 1993; Atkinson, 2001; Webster, 2001; Cristea & De Bra, 2002]. If cognitive styles are individual and non-changing, they could provide significant basis for modelling learners towards personalisation [Uruchurtu et al., 2005].

3.2.2 Models and Classifications

Since the early 1940s relevant research on cognitive styles has been undertaken, producing a series of models and classifications constructed from what investigators thought represented style dimensions. At different times, different researchers have tried to identify and/or classify them: Messik [1984] identified nineteen different labels referred to as cognitive or learning styles; Riding and Cheema [1991] presented over thirty such classifications; Armstrong [1999], in a research of the relevant literature, identified fifty four dimensions on which cognitive style had been differentiated.

Despite much research, there is no accepted, far less standardised taxonomy of cognitive styles. To assess the extent of the differences among different models and classifications, some of these are summarised in Table 3.1.

Model	Description	Theorist(s)
Field-dependent & Field-independent	The degree of emphasis placed on internal or external referents when processing information.	Witkin [1978]
Levelling-sharpening	The extent to which individuals assimilate and emphasise details and changes in new information.	Gardner & Long [1962]
Impulsivity & Reflectiveness	Tendency for quick as against a deliberate response. Impulsive people tend to respond more quickly and to make more errors.	Kagan et al. [1973]
Converging-diverging	Narrow, focused, logical, deductive thinking compared to a broad, open-ended, associational thinking to solve problems.	Hudson [1968]
Holist & Serialist	The tendency to work through learning tasks or problem solving incrementally or globally.	Pask [1988]
Concrete-sequential, Concrete-random, Abstract-sequential & Abstract-random	The learner learns through concrete experiences and abstraction either randomly or sequentially.	Gregorc [1982]
Assimilators & Explorers	Disposition for seeking familiarity or novelty in the process of problem solving.	Martinsen & Kaufmann [2000]
Adaptors & Innovators	Personal response to change, creativity and problem solving. Adaptors prefer conventional, established procedures; innovators prefer either restructuring or new perspectives.	Kirton [1994]

Model	Description	Theorist(s)
Verbaliser - Imager	The extent to which verbal or visual strategies are used to represent knowledge while thinking.	Riding & Cheema [1991]
Wholist-Analytic	Tendency for the individual to processing information in parts or as a whole.	Riding & Cheema [1991]
Converger, Diverger, Assimilator & Accommodator	Emphasises four modes of the learning process: concrete experience, reflective observation, abstract conceptualisation and active experimentation, from which four basic learning styles are identified.	Kolb [1984]
Activist, Theorist, Pragmatist & Reflector	Preferred modes of learning which shape an individual approach to learning.	Honey & Mumford [1995]
Auditory, Visual & Tactile/Kinaesthetic	Learners need information to be presented orally, visually, or structured around dynamic activities.	Sarasin [1999]
Approaches to Studying	Distinctive forms of motivation are associated with contrasting learning processes, affecting the outcome of learning.	Entwistle [1988, 1988b]
Approaches to learning	An integration of approaches to study with cognitive and motivational components.	Biggs [1987]
Learning Processes	The quality of thinking which occurs during learning relates to the distinctiveness, transferability and durability of memory and fact retention.	Schmeck [1983]
Learning Style Inventory	The learner's response to key stimuli: environmental (light, heat); sociological (peers pairs, adults, self); emotional (structure, persistence, motivation); physical (auditory, visual, tactile); psychological (global-analytic, impulsive-reflective).	Dunn & Griggs [2000]
Sensing-Intuitive, Visual-Verbal, Inductive-Deductive, Active-Reflector & Sequential-Global	Learners' preferred orientation to studying is identified using five spectrums relating to information presentation, structuring and the type of media elements included.	Felder & Silverman [1988]

Table 3.1: Cognitive styles and learning styles: labels, models and classifications.

Another commonly shared view is that individual differences between human beings are possibly due to differences in the left/right hemispheric specialisation of the brain [Kolb, 1984]. Research studies during the 1960s demonstrated that the left side of the brain is the seat of language abilities and specialises in primarily analytic, rational and sequential information processing, whereas the right side is more visual and processes intuitively, holistically and randomly.

More recent research confirms that both sides of the brain are involved in nearly every human activity; therefore some researchers now regard this split brain formulation to be an oversimplification of the facts. Nonetheless, others continue to report evidence consistent with this theory, arguing that most people seem to have a dominant side and tend to process information using that dominant hemisphere of the brain [Kolb, 1984; Atkinson, 2001].

It can be observed that, beyond labels and names, most of the dimensions proposed by researchers in the field tend to consider the position of the individual on a continuum between two extremely different characteristics. Table 3.2 shows a summary of the main differences reported between pairs of constructs.

Construct	Dimensions	
Left-Right cerebral hemisphere	*Left cerebral hemisphere* Seat of language, specialised in analytic, logical and sequential information processing.	*Right cerebral hemisphere* Visual side, specialised in primarily intuitive, holistic, and simultaneous information processing.
Linear vs. Holistic	*Linear* Thinking in terms of linked ideas, one thought following another, often leading to a convergent solution.	*Holistic* Perceiving the overall pattern and structure, often leading to divergent conclusions.
Sequential vs. Random	*Sequential* Processing in sequence –in order.	*Random* Random approach for processing information, it might be likely to flit from one task to another.
Symbolic vs. Concrete	*Symbolic* No trouble processing symbols such as letters, words and mathematical notations.	*Concrete* Would prefer things to be concrete, to see, feel or touch the real object, or to see words in context.
Logical vs. Intuitive	*Logical* Processing information in a logical manner and drawing decisions on logic proof.	*Intuitive* Using intuition while processing information and making decisions based on feelings.
Verbal vs. Non-verbal	*Verbal* Using verbal representations to depict information when thinking. Little trouble expressing ideas in words.	*Non-Verbal* Using images to depict information when thinking. Often difficult finding the right words.

Table 3.2: Differences between dimensions of analysis.

3.3 COGNITIVE AND LEARNING STYLES IN WEB-BASED LEARNING

Underlying the distinctions made between cognitive characteristics, there is a general model of cognition that emphasises how data from the world is perceived, input to the brain, stored, how it is processed, and how solutions and decisions are expressed [Benyon, 1993].

In this regard, it is possible to argue that if the preferred style for processing information of an individual is identified, then different strategies would allow them to acquire knowledge more or less easily and to a more or less efficient extent [Jonassen & Grabowski, 1993].

3.3.1 Cognitive and Learning Styles in Educational AH Systems

Several Web-based systems providing adaptation to users' cognitive or learning style have been created. Table 3.3 presents some of them and the styles they implement.

System	Cognitive/Learning Style
ARTHUR [Gilbert & Han, 1999]	Visual, Auditory, Text Sarasin [1999]
AES-CS [Triantafillou et al., 2003]	Field-dependent, Field-independent. Witkin [1978]
INSPIRE [Papanikolaou et al., 2003]	Activist, Pragmatist, Reflectors, Theorist Honey & Mumford [1995]
TANGOW [Paredes & Rodríguez, 2004]	Sensing, Intuitive Felder-Silverman [1988]
AHA! [Stash et al., 2004]	Activist, Pragmatist, Reflectors, Theorist Honey & Mumford [1995]
MOT [Stash et al., 2004]	Diverger and Converger Kolb [1984]

Table 3.3: Educational AH systems implementing cognitive or learning styles.

Adaptation in ARTHUR [Gilbert & Han, 1999] is achieved by providing different media representations according to the style of the learner. *Visual* learners are presented with visually stimulating learning materials, such as animations or drag and drop exercises. *Auditory* representations are achieved using sounds and streaming audio. Students of *Text* style are provided with text-based explanations and assessment tasks.

In the case of the AES-CS system [Triantafillou et al., 2003], *field-dependent* learners are provided with navigational support, such as concept map, graphic path indicator and advanced organisers in order to help them structuring the knowledge domain. Adaptive navigation support is also provided to guide students through the learning materials.

Field-independent learners, on the other hand, are provided with a learner control option in the form of a menu, from which they can proceed with the course in any order.

INSPIRE [Papanikolaou et al., 2003] presents their users with different sequences of alternative content according to their style. Learning content is organised in modules of different types: theory, exercise, example and activity; the order of their presentation is adapted according to the learning strategies preferred by students. The module "activity" appears at the top of the content page for *Activists*. For *Reflectors*, the module "example" is of higher priority. Since *Pragmatists* are exercise-oriented learners, the "exercise" module is placed at the top of the content page. For the *Theorists*, the "theory" module is the initial one. INSPIRE also implements adaptive navigation to help students to find their way through the learning content.

In the more recent version of TANGOW [Paredes & Rodríguez, 2004], adaptation is achieved by implementing curriculum sequencing techniques. Knowledge is represented by means of teaching tasks that can be of "exposition" type or "practical" type. With *sensing* learners the practical strategy to organise and present the teaching tasks is adopted, while for *intuitive* students, the exposition strategy is followed.

While the AH systems described above have been developed for specific subject domains, AHA! and MOT [Stash et al., 2004] are authoring tools. Therefore, adaptation to the cognitive or learning style of the student is a design issue that the course designer has to plan and implement according to their requirements. In AHA!, the learning content is organised using a hierarchical structure of concepts and specifying prerequisite relationships between them. Creating an application to adapt the presentation and sequencing of learning content for *activist*, *pragmatist*, *reflectors* and *theorist* would require that course concepts are designed from different perspectives, i.e. activities, exercises, examples and explanations. The sequence in which the system would present these sub-concepts depends on the relationships defined between these and their parent concepts as well as the conditions that determine when concepts become desirable, i.e. the attributes of the individual learner. In MOT the conceptual structure of the domain is realised using a schema rather than a hierarchy, which facilitates re-usability of instructional strategies within different subjects.

The systems described above are some of the educational AH applications introduced over the past few years providing adaptation to cognitive and learning styles mainly through adaptive content, curriculum sequencing and navigational support. In these systems, the choice of learning or cognitive style seems to be determined by the available technology and the possibility of creating a quantitative model suitable for implementation in a computer system [Brown et al., 2006; Stash et al., 2004].

It has also been noted [Stash et al., 2004] that most of the systems presented assess the students' learning style and classify them into stereotypical groups without updating this information taking into account the subsequent interaction with the system. This may be a disadvantage since, as it has been argued before, learning styles can vary for the same individual depending on internal and external factors of the learning situation.

Another issue is that the emphasis of most researchers in the field of AH has been on the pragmatics of the development –i.e. modelling fairly complex psychological constructs, or adapting existing models to particular architectures [Brown et al., 2006]. While most AH systems that incorporate cognitive or learning styles are based on the notion that matching instructional strategies to the learners' style improves their performance, empirical support for this conception is scarce in the field.

Results from studies carried out in the past to investigate the effects that different variables have on individuals with different styles have been ambiguous, and while some of them have found a consistent relationship between style and learning, others have found no noticeable effect. Some of these studies are presented in the next section.

3.3.2 Using Cognitive and Learning Styles, some Evaluation Studies

Computer-Based Learning Materials

Experimental studies have been conducted to determine the extent to which cognitive and learning styles are related to the users' preference for learning materials delivered through the use of computers and related technologies. In 1991 for example, Riding and Cheema used Honey and Mumford's model of learning styles and concluded that *Activist* was the group most comfortable with CAL. Later on, using Kolb's Learning Style Inventory with students in Higher Education, Lord [1998] found that low achievers in CAL environments were predominantly of *Accommodator* and *Diverger* styles. In 1999 McKenzie et al. carried out a study concerning computer-supported cooperative learning using Honey and Mumford's model. They found that *Theorists* showed the strongest preference for CAL, while *Activists*, initially enthusiastic users, became bored with the novelty value and reduced their usage over time. In turn, the lack of the immediate dynamic of the real classroom caused frustration for *Pragmatists*.

Enquiring about differences in performance, in 1999 Riding and Grimley compared learning from CD-ROM multimedia materials on science with performance using traditional methods. They found a significant interaction between the *Wholist-Analytic* style and mode of presentation, and their effect on information recall. Researchers noted that *Analytics* did not learn as well as *Wholists* from using multimedia probably because the computer has a limited viewing window that exacerbates their tendency to see information in parts, which ultimately debilitated their learning performance.

Response to Different Modes of Presentation

In 1993 Riding and Douglas, using the Riding and Cheema's model of *Verbaliser-Imager* cognitive style, argued that *Verbalisers* tend to perform better than *Imagers* in learning environments where the material is presented in a textual/auditory format, whereas *Imagers* tend to score higher when the learning material is presented in a more graphical format.

However, in a later study, Wei [2001] found no simple effects relating presentation mode and *Verbaliser-Imager* cognitive style with student learning performance while evaluating a training program on statistics. Similarly, Brown et al. [2006] carried out an experiment to investigate the impact of visual/verbal personalisation of an adaptive, Web-based educational system in student academic performance. Undergraduate and postgraduate students of computer sciences used a Web-based revision guide previous to their final examination. Using the Felder-Silverman model of learning styles, participants were placed into a group were the learning materials were either matched, mismatched or neutral (i.e. a mix of visual and verbal content) to their style. Academic performance of students was determined by their results in a self-assessment task included in the revision guide, as well as the overall module mark. While qualitative feedback from the participants indicated that they found the revision guide an enjoyable and useful resource, no significant difference was observed between the academic performance of those students who used the revision guide and those who did not use it. Nor was there a correlation between the amount of use of the revision guide and the students' academic performance.

Information Structures

Regarding hypertext, hypermedia and Web-based learning materials, research has been done related to the kind of information structures in use; the theoretical underpinning being that the non-linear structure of hypertext should allow a greater degree of flexibility in the way educational information is presented in comparison to ordinary text [Graff, 2003]. Such systems could allegedly help users to derive an understanding of the structure of the system more rapidly, and in this way facilitate a more efficient, deep learning. However, hypertext has the consequence of fragmenting its content into several smaller units, reducing in this way the overall meaning mainly because of the lack of "narrative" between screens [Graff, 2003].

Fragmentation of meaning in hypertext environments has been a major concern among researchers in the field. In 1993, for example, using Ridings and Cheema's cognitive style dimensions, Riding and Douglas suggested that *Analytic* individuals were superior at seeing structure, and therefore it would be possible that the fragmentation of information could be more advantageous to them since they would be able to apprehend the system structure more easily, facilitating in this way their performance.

Later on, using Riding and Cheema's *Wholist-Analytic* cognitive style, Graff [1999] found that *Wholists* benefited from computer-based instruction if the mode of delivery provided an organisational aid to learning. By contrast, when the material was less structured and the learner must provide organisation, then such an environment favoured *Analytics*.

In terms of the hypertext structure, Graff [2003] conducted an experimental study to enquire whether matching a hypertext architecture to the cognitive style of the user could facilitate performance. Using a historical passage, a hypertext document was presented as one of three architectures –linear, hierarchical or relational. Using Riding and Cheema's cognitive style dimensions, he found that *Intermediate* learners – individuals who fall between *Wholist* and *Analytic* – performed better in the relational architecture, possibly because they seem to possess the characteristics of both *Analytics* and *Wholists*, which facilitate their learning performance. Graff also observed that *Bimodal* individuals –individuals who fall between *Verbalisers* and *Imagers*– performed better in the hierarchical architecture.

3.3.3 Discussing the Empirical Evidence

Results from previous empirical studies have been ambiguous as to whether different variables of the instructional setting relate to the cognitive or learning style of students. However, most authors in the field of individual differences for learning seem to agree in that different instructional strategies are effective just with certain students [Kolb, 1984; Schmeck, 1988; Riding & Rayner, 1998; Sarasin, 1999; Dunn & Griggs, 2000]. They suggest that to teach more effectively and to support the individual process of knowledge construction of each student, a better understanding of individual differences and their effect on learning is required. This stance seems to explain why, in spite of indefinite empirical findings, the number of adaptive, Web-based learning systems enhanced with the capability of assessing student's style and adapting instruction accordingly is still increasing. This also highlights the need for further research in the field exploring the relationship between key characteristics of the individual's style and possible interface settings [Brusilovsky, 2001].

While the findings presented above derive from a body of research dealing with both cognitive and learning styles, most authors share the opinion that learning styles are not stable characteristics of individuals [Kolb, 1984; Schmeck, 1988; Riding & Rayner, 1998; Dunn & Griggs, 2000] and may be better considered orientations to studying, rather than styles. If, on the contrary, cognitive styles are stable characteristics of learners, it seems potentially useful to use them to identify some key characteristics of learners for the design of adaptive interfaces for Web-based learning materials.

3.4 AN INCLUSIVE MODEL OF COGNITIVE STYLES

The multiplicity of models and classifications related to cognitive styles has led to a certain extent of confusion. In an attempt to integrate much of the earlier work in the field, Riding and Cheema [1991] analysed over 30 different labels and models of style previously identified by a number of researchers. They argued that many different labels used to categorise cognitive styles and learning styles were different conceptions of the same dimension. After reviewing the descriptions of several constructs, as well as correlations between them, methods of assessment, and effect on behaviour, they concluded that the terms could all be grouped into two principal cognitive style dimensions and a number of learning strategies. They referred to the dimensions as *Wholist-Analytic* and *Verbaliser-Imager* (Figure 3.1).

The *Wholist-Analytic* style refers to the tendency of individuals to **organise** information in parts or as a whole, while the *Verbal-Imager* style is concerned with the tendency of individuals to use images or verbal structures to **represent** information verbally or in mental pictures when thinking.

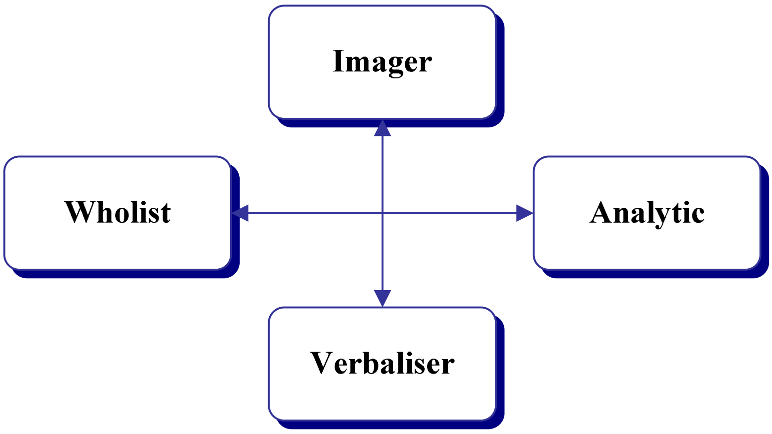


Figure 3.1: Cognitive style dimensions.

3.4.1 The Cognitive Styles Analysis Test

In order to assess both dimensions of style, Riding [1997] designed the Cognitive Styles Analysis (**CSA**) test, a computerised assessment that measures an individual's tendency to think visually or verbally, and to process information holistically or analytically. It aims to overcome assessment problems associated with traditional self-reported rating scales used in most measures of style, as well as to positively assess both ends of each dimension of style rather than just one end of the spectrum as observed in other tests.

The CSA test consists of two parts, the first one to assess the position of individuals on the *Verbaliser-Imager* style, and the second one to determine their position on the *Wholist-Analytic* dimension.

In the first part of the test, participants are presented with statements one at a time and asked to judge them true or false. Half of these statements contain information about conceptual categories (e.g. are these objects of the same type?), while the rest describe the appearance of items (e.g. are these objects of the same colour?). Half of the statements of each type are true.

It is anticipated that *Imagers* would respond faster to the appearance statements since the objects could be depicted as mental pictures and they could then use these images to make comparisons rapidly. Conversely, it is assumed that for the items in the conceptual category, *Verbalisers* would respond more quickly because the semantic conceptual category is verbal in nature and cannot be represented in visual form.

The computer records the response time to each statement and calculates a verbal-imagery ratio. A low ratio corresponds to a *Verbaliser* and a high ratio to an *Imager*, with the intermediate position described as *Bimodal*.

The second part of the assessment comprises two sub-tests for assessing the *Wholist-Analytic* style. The first of these sub-tests presents pairs of complex geometrical figures to the user and asks them to determine whether the figures are the same or different. Since this task involves judgements about the overall similarity of the two figures, it is expected that *Wholist* would be more accurate in their responses.

The second sub-test displays pairs of geometrical figures, one of a single shape (e.g. a square or a triangle) and the other of a complex figure. Individuals are required to indicate whether the simple shape is contained in the complex one or not. This tasks requires a degree of disembedding of the simple shape from the complex figure, therefore it is assumed that a relatively faster response would be possible by *Analytics*. The computer again records the response times and calculates a wholist-analytic ratio. A low ratio corresponds to a *Wholist*, and a high ratio to an *Analytic*; the ratios in between are labelled as *Intermediate*.

Since the purpose of the tasks is that participants carry them out in a way that reflects their usual manner of processing information, individuals are not made aware that the test uses response times to determine their cognitive style; and because response ratios are used, the overall speed of the user does not influence their style result. Dimensions in the model are independent of one another, and the position in one dimension does not influence position on the other during the test. Several studies have been carried out employing the CSA test to explore the educational effects of cognitive styles in the learning context. Summaries of these studies can be found in Riding 1997, and Riding & Rayner 1998, all of them contributing to the validity of the construct.

3.4.2 The VICS and Extended CSA-WA Test

Peterson et al. [2003] conducted research on the stability and internal consistency of the CSA test by comparing performance of the original test and a new parallel version. They found that the *Verbaliser-Imager* style ratio and the *Wholist-Analytic* style ratio have poor test re-test reliability ($r < 0.32$). They showed that an extended version of the CSA's *Wholist-Analytic* dimension (**E**xtended **CSA-WA**) improved the test reliability to a satisfactory level (internal consistency $r = 0.72$; reliability $r = 0.55$) and they designed a new test for the *Verbal-Imager* dimension (**VICS**) with acceptable internal consistency ($r > 0.72$) and test re-test reliability ($r = 0.56$).

The VICS sub-test comprises two tasks. During the first task, participants are presented with pairs of items and are required to judge them as being natural, man-made or a mixture (i.e. one natural and one man-made). For the second task users are again presented with pairs of items, but are then required to judge whether one is bigger/smaller than the other or both roughly the same size. The total number of the stimuli used is 232, and its component break down is detailed in Table 3.4. For the extended version of the CSA-WA, the number of stimuli was increased to 80 statements. Its component break down is detailed in Table 3.5.

Verbal Imagery Cognitive Style Test											
Verbal Task (116)						Imagery Task (116)					
Words(58)			Pictures (58)			Words(58)			Pictures(58)		
N(26)	M(26)	Mx(6)	N(26)	M(26)	Mx(6)	B(26)	S(26)	E(6)	B(26)	S(26)	E(6)

Key: N=Natural, M=Man-made, Mx=Mixed, B=Bigger, S=Smaller, E=Equal

Table 3.4: Component break down in the Verbal Imagery Cognitive Style (VICS) sub-test. [Source: Peterson, 2003].

Extended CSA-WA			
Wholist Task (40)		Analytic Task (40)	
Original CSA Wholistic items (20)	New Wholistic items (20)	Original CSA Analytic items (20)	New Analytic items (20)

Table 3.5: Component break down in the Extended Wholist-Analytic (E-CSA-WA) sub-test. [Source: Peterson, 2003].

3.5 USING COGNITIVE STYLES IN ADAPTIVE SYSTEMS FOR LEARNING

As outlined at the beginning of this chapter, dealing with cognitive differences requires a 3-stage approach where the first step entails the assessment of the differences and the identification of an appropriate way of measuring them. Given the extensive research supporting Riding and Cheema's [1991] model of cognitive styles, and considering the availability of a validated assessment test for such a model (i.e. Peterson's VICS&E-CSA-WA test), it is proposed to use them as reference framework for identifying essential characteristics of cognitive styles, which in turn may be useful to determine a suitable design to cater for the individual needs of different learners.

In Chapter 2, different approaches for providing a more personalised learning experience were discussed and particularly the approach of educational AH systems and their capability to automatically adapt their functionality and/or appearance to new conditions. As suggested by Benyon [1996], the complexity of an adaptive mechanism depends on the model it possesses of itself, the model of the system with which it can interact, and a model of the interaction. Accordingly, to provide the learner with the learning scenario that best fits to their particular needs, an adaptive learning system would require the convergence of several modelling dimensions, such as a model of the domain (ontology mapping, content, context, structure, composition), a learning model (derived from the rules and heuristics governing the presentation of learning materials to support a particular learning scenario), and a learner model (cognitive and personal data profile). The strategy of interaction can be seen as a product of the combination of these factors, but driven mainly from the personal requirements of the learner.

In this conceptual structure the adaptation model is regarded as an active interaction between the system and its users, one that is capable of inferring and evaluating the user's intentions and actions in order to exhibit a more cooperative behaviour. Since the dialogue between the user and the system is mediated by the interface, two issues become central: the construction and use of an explicit model of the user's key cognitive characteristics, and an interface design capable of demonstrating the adaptive behaviour that is expected from the system.

3.5.1 Key Characteristics of Cognitive Styles

In order to address the relevance of the cognitive styles in the design of adaptive interfaces for Web-based learning materials, some key defining attributes have been identified and organised under Riding and Cheema's dimensions of analysis. These are summarised in Table 3.6.

Some instructional conditions have been identified that capitalize on the key characteristics of the individuals' cognitive style [Kolb, 1984; Entwistle, 1988, 1988b; Ramsden, 1988; Schmeck, 1988; Benyon, 1993; Riding & Rayner, 1998; Sarasin, 1999; Dunn & Griggs, 2000; Webster, 2001; Cristea & De Bra, 2002; Laurillard, 2002]. These have been summarised in Table 3.7.

Analytics	Wholists
▪ Process information from parts to the whole.	▪ Process information from the whole to parts.
▪ Generates structure. Organised and structured, able to establish a meaningful structure.	▪ Accepts structure. Not highly organised, less likely to impose a meaningful organisation when there is no structure.
▪ Sequential approach. Take pieces, line them up, arrange them in a logical order and then draw conclusions.	▪ Random approach. Might flit from one task to another.
▪ Internally directed. Possess internal cues to help them solve problems. Self-defined goals and reinforcements.	▪ Externally directed. Require external clues to help them solve problems. Require externally defined goals and reinforcement.
▪ Reality-based, deal with things the way they are.	▪ Require feedback and reality checks constantly.
▪ Usually adjust to the environment.	▪ Not easy to adapt to the environment.
▪ Want to know the rules and follow them.	▪ Remember well what they become emotionally involved in.
▪ Decisions are made on logic-proof.	▪ Decisions are based on feelings.
▪ Conceptually oriented.	▪ Factually oriented.
▪ Impersonal orientation.	▪ Get feelings/ decisions from others.
▪ Intrinsically motivated, enjoy individualised learning.	▪ Extrinsically motivated, group oriented and collaborative work preferred.
▪ Friendly but restrained, probably formal.	▪ Attentive to social information. Informal, extraverted.
▪ Acquire information within a conceptual scheme.	▪ Acquire unrelated facts.

Verbalisers	Imagers
▪ Tendency to use verbal representations to depict information when thinking.	▪ Tendency to use images to depict information when thinking.
▪ Understands semantic complexity.	▪ Understand visuals.
▪ Preferred mode of expression: words rather than illustrations.	▪ Preferred mode of expression: illustrations and diagrams rather than words.
▪ Prefer to read about the idea.	▪ Prefer to have someone show them.
▪ Objective task orientation.	▪ Subjective self-orientation.

Table 3.6: Key defining attributes of cognitive styles.

Analytic	Wholist
▪ Inquiry and discovery instructional methods.	▪ Deductive or procedural instruction sequence.
▪ Use analytical approach to present information.	▪ Use global approach to present information.
▪ Provide an independent learning environment.	▪ Benefit from well-organised, well-structured material.
▪ Offer content outlines and post organizers.	▪ Offer deliberate structural support with salient cues, especially organisational cues as advance organizers.
▪ Provide minimal guidance and direction.	▪ Provide clear, explicit directions and the maximum amount of guidance.
▪ Provide content resources and reference material.	▪ Provide extensive feedback.
▪ Provide team building exercises.	▪ Provide a social learning environment.
Verbaliser	**Imager**
▪ Learn best when information presented in verbal form.	▪ Learn best from images, diagrams or pictures.
▪ No trouble processing symbols — letters, words and mathematical notations.	▪ Want things to be concrete, to see the real object.
	▪ Presenting special text in windows or boxes.
	▪ Underlining, visual cueing in text.

Table 3.7: Instructional conditions that capitalize on different cognitive styles.

3.5.2 Adaptive Variables

In order to accommodate the individual differences outlined above, as well as the instructional conditions that seems to capitalize on such characteristics, a learning system should exhibit adaptive behaviour based on, at least, the variables described in Table 3.8.

Sequence of Instruction

Analytic people tend to approach the learning content in a deductive manner, following an abstract to concrete sequence, whereas *Wholist* learners would tend to approach the learning task following a concrete to abstract sequence. Adaptive presentation techniques –e.g. conditional text, page variants– can be implemented to provide the content sequence that best fits the preferences of the learners. Some educational AH systems that have employed this approach include TANGOW [Paredes & Rodríguez, 2004] and INSPIRE [Papanikolaou et al., 2003], and can also be implemented in MOT and AHA! [Stash et al., 2004].

Adaptive variables	Analytic	Wholist	Verbaliser	Imager
Sequence of Instruction	▪ Abstract to concrete sequencing	▪ Concrete to abstract sequencing		
Content representation			▪ Verbal	▪ Highly imager
Content structuring	▪ Post-organizers	▪ Advance Organizers	▪ Textual outliners	▪ Graphic organizers
Control strategy	▪ User in control of sequence	▪ System in control of sequence		
Instructions & Feedback	▪ Minimal instructions ▪ Minimal feedback	▪ Maximum amount of instructions ▪ Extensive feedback		

Table 3.8: Adaptive variables for an adaptive learning system based on cognitive styles.

Content Representation

Since *Verbalisers* seem to learn best when information is presented in verbal form, and *Imagers* when diagrams and/or pictures are used, learning materials should be presented in their preferred mode. Adaptive techniques could be implemented to provide, whenever possible, the same content using different media elements; some examples of such techniques are used in ARTHUR [Gilbert & Han, 1999] and INSPIRE [Papanikolaou et al., 2003].

Content Structuring

Analytics would prefer an independent learning environment, and to impose their own structure on the material provided. Content outlines would be helpful as well as post-organizers. Conversely, structured lessons would help *Wholists* better since they seem to prefer material that is organized for them, as well as navigational tools such as concept maps. Some of these adaptive strategies have been applied in AES-CS [Triantafillou et al., 2003], INSPIRE [Papanikolaou et al., 2003] and TANGOW [Paredes & Rodríguez, 2004] and could be implemented in MOT and AHA! [Stash et al., 2004].

Control Strategy

The control strategy is related to the content structuring in the system, and refers to the degree of control that the system provides for the students to progress through the learning material. *Analytics* could have control over the sequence of the content, whereas *Wholist* learners could be guided by the system. Adaptive navigation techniques can be implemented to provide the appropriate control according to the learners' cognitive style, examples of these techniques are found in AES-CS [Triantafillou et al., 2003] and INSPIRE [Papanikolaou et al., 2003].

Instructions and Feedback

It seems that *Wholists* would perform better when explicit directions, extensive feedback and maximum guidance are provided throughout the system. On the contrary, *Analytic* individuals would appreciate and possibly perform better when instructions and feedback are kept to the minimum.

3.6 AN EARLY PROTOTYPE: LEARNINT

As stated before, a fully functional adaptive learning system would require the convergence of various modelling dimensions such as the domain model, the learner model and the adaptation model. These components should interact to adapt to different variables of the learning process, i.e. adapting the way instructional material is structured, adjusting its mode of presentation, modifying the sequence of instruction, allowing different degrees of user control as well as different amount of instructions and feedback provided (adaptive variables, Table 3.8). While some educational AH systems have already implemented some of these variables to provide adaptation, most of them have focused on specific issues such as navigation support, content sequencing or mode of presentation. The approach proposed here is a multivariable one that may support the key characteristics of cognitive styles previously identified in a comprehensive manner.

As part of the development of an adaptive system based on the framework described above, an application called **LEARNINT** (the Learning Interface) was developed as a case study to assess some of the critical variables for the design of adaptive interfaces for Web-based learning materials based on the students' cognitive style.

3.6.1 Design Rationale: Selecting the Interface Styles

LEARNINT was developed using content extracted from the "Computer Hardware" module which is available to students of the MSc (IT) degree in the School of Mathematical and Computer Sciences at Heriot-Watt University in Edinburgh, Scotland.

LEARNINT comprises two extremely different interfaces. The first design (W/I) is *Imager* and *Wholist*, covering some introductory concepts from the topic "Combinational Circuit Design". The second interface (A/V) is *Verbaliser* and *Analytic* and its learning content was extracted from the topic "Relational Circuit Design". In both cases learning material allow for a 30-minute work session.

The rationale behind the selection of these interface styles is that they represent the extreme cases when the cognitive style dimensions are used in combination.

As previously discussed (section 3.4) according to Riding and his colleagues [Riding & Cheema, 1991; Riding & Rayner, 1998] there are two fundamental components of cognitive style, namely the *Wholist-Analytic* and the *Verbal-Imagery* dimensions. Further research has been carried out examining the extent to which these two style dimensions are truly independent of one another, whether there are physiological basis to support them, and whether they are distinct from other dimensions of individual differences. A summary of some of these studies can be found in Riding & Rayner [1998] arguing that the two style dimensions have been found consistently distinct from one another throughout a large number of studies in that the position of an individual on one dimension does not affect their position on the other. Also, that a link has been observed between both of the style dimensions and brain cortical activity, which supports the argument that there are physiological basis for the proposed cognitive style dimensions. Additional consideration of other dimensions of individual differences, such as intelligence, personality and gender also indicates that these attributes have effects that are independent of those of style, and that they are therefore different sources of influence.

This body of research suggests that cognitive style dimensions can be independently analysed from one another. Thus, examining the influence of each dimension on user preferences or exhibited behaviours could include, for example, the relationship between an individual's position on the *Verbal-Imagery* dimension and their preferences for visual or textual learning materials; or the influence of an individual's *Wholist-Analytic* style on their organisational tendencies.

It has also been suggested that cognitive style dimensions can be examined in combination [Riding & Rayner, 1998]. Hence, results from the cognitive analysis tests determine whether a person scores as, for example, *Wholist* **and** *Imager*, or as *Intermediate* **and** *Verbaliser*, and so forth (possible style combinations are depicted in Figure 3.2). It is argued that the combination of the specific characteristics derived from the individual's position on each dimension will determine their unique cognitive style [Riding & Cheema, 1991; Riding & Rayner, 1998] (section 3.5.1 provides more detail about the specific characteristics derived from each cognitive style dimension).

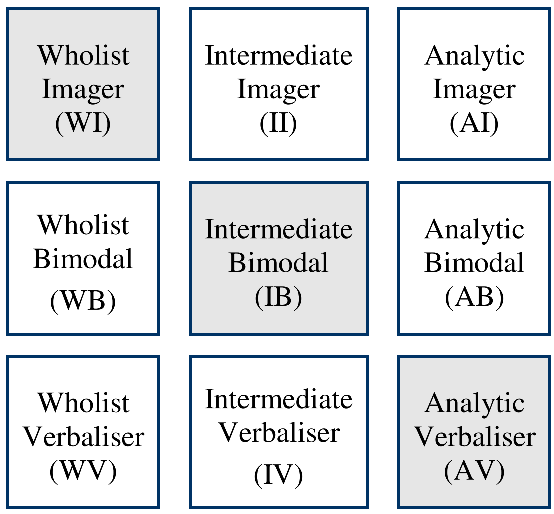


Figure 3.2: Possible combinations of cognitive style dimensions.
[Source: Riding & Rayner, 1998].

Moreover, Riding & Rayner [1998] argue that each style dimension may complement or intensify each other. It has been observed that where a dimension of an individual's cognitive style is not appropriate to a task, this person is likely to employ a strategy of using, where possible, the other dimension as an alternative. For example, if someone of *Analytic-Imager* style were trying to form an overview of a given situation, since the analytic aspect of their style would not provide this overview, they could attempt to use the "whole-view" property of their imager style as a substitute. Likewise, if another person were *Wholist-Verbaliser*, then since the wholist facility does not support analysis, they may use the "analytic" property of verbalisation to supply it.

On this basis, the possible combinations of the cognitive style dimensions can be ordered approximately from the **least** *Analytic* / **most** *Wholist* style to the **most** *Analytic* / **least** *Wholist* one, where the *least Analytic* is the *Wholist-Imager* style and the *most Analytic* is the *Analytic-Verbaliser* style (Figure 3.3). Neither of these extremes has the facility to use the other dimension to supply the missing facility.

Extreme Wholist								**Extreme Analytic**
WI	WB	II	WV	IB	AI	IV	AB	AV

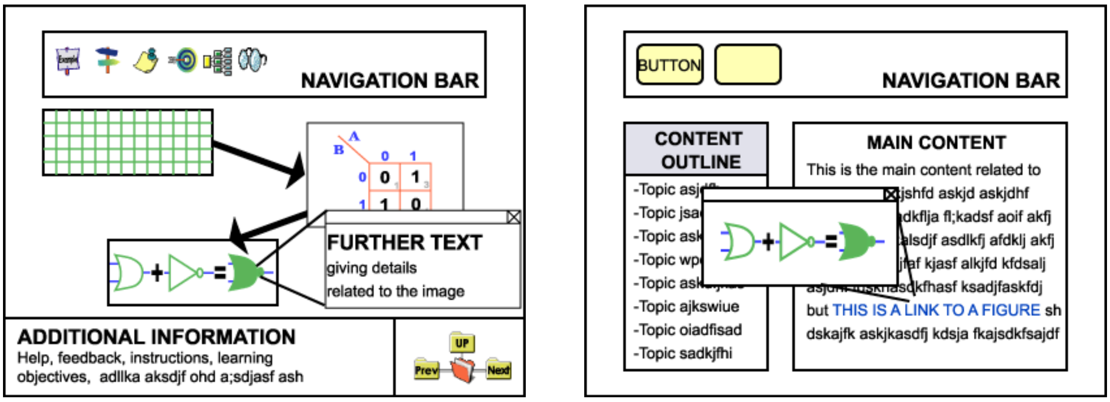
Figure 3.3: Cognitive styles ordered from *extreme Wholist* to *extreme Analytic*. [Source: Riding & Rayner, 1998].

Given that LEARNINT intended to validate the use of the variables previously identified in the research, it was conceived as a prototype rather than a fully functional AH system. It was expected that through the use of LEARNINT as test vehicle in an empirical study, evidence would be obtained in support of the design approach put forward in this thesis. As such, it was considered more convenient to explore the use of the most extreme cognitive styles, which would provide the opportunity to incorporate very different user interface design features rather than the more subtle designs that would derived if other combinations of cognitive style dimensions were used.

Therefore, following Riding & Ryner [1998] in that cognitive style dimensions used in combination exhibit their most unitary behaviour in terms of *Wholist-Imager* and *Analytic-Verbaliser* styles, these were the interface styles implemented in LEARNINT.

3.6.2 Design Rationale: Interaction Design

The initial storyboard of LEARNINT is presented on Figure 3.4. In this early sketch the interaction between cognitive style and interface design was sought through the structure of the learning content, its mode of presentation and its type of content. The salient feature was, however, the content's mode of presentation: one interface should present information in verbal form and the other should display information in terms of images, diagrams or pictures; that concept was extended to include all elements in the screen including, for example, buttons and navigational aids. The actual interfaces are shown in Figures 3.5 and 3.6.



A) Wholist/Imager Interface B) Analytic/Verbaliser Interface

Figure 3.4: LEARNINT initial story board.

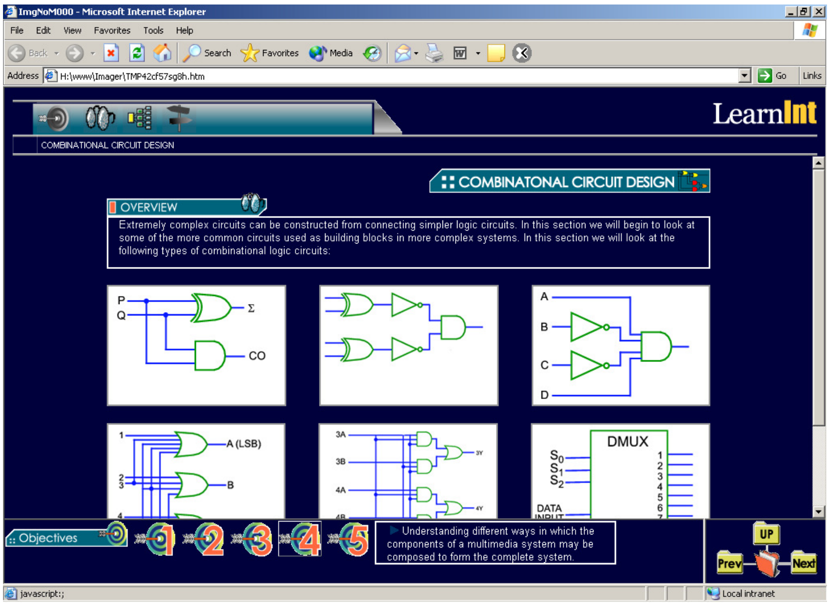


Figure 3.5: Wholist/Imager interface design.

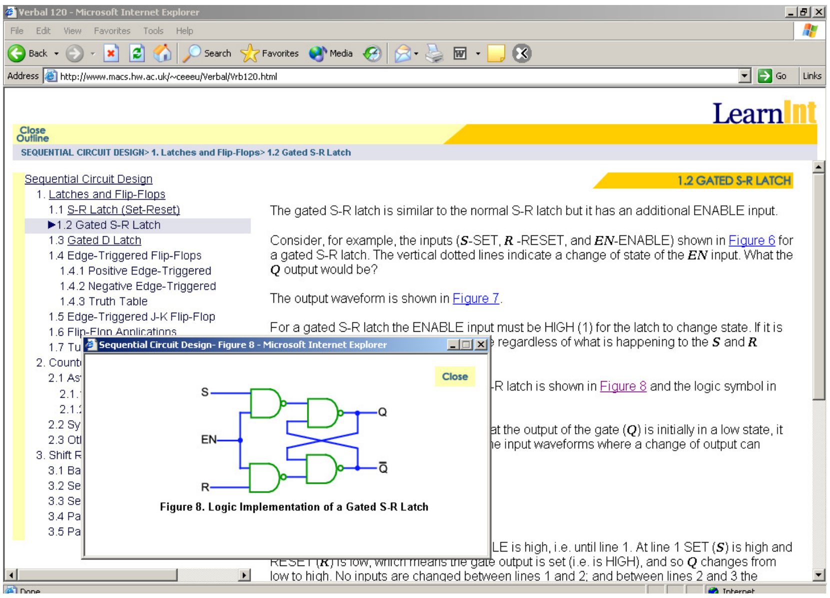


Figure 3.6: Analytic/Verbaliser interface design.

In terms of the conceptual structure of the content, the logic sequence established in the original design of the learning material was observed. However, advance organizers were included for the *Wholists* who seem to benefit from summaries placed before the main segment of information.

In order to define the size of the information step – i.e. how much information to present at a time – it was important to consider that the size of the viewing window in the computer apparently aggravates the *Analytics'* tendency to see material in parts and also that fragmentation of content into several smaller units reduces its overall meaning. Therefore, in the final design, each page of the hypertext structure contains a complete unit of information (a concept), once more following the original structure used by the author. Yet, for the A/V design a content outline was placed so that *Analytics* would be able to see the whole structure of the material, and to follow the sequence they consider best, hence increasing their sense of control. Conversely, for the W/I interface the sequence of the material is defined by the system in a linear approach; however, the content was structured in small chunks as to allow for its graphical presentation –for example, text fragments are kept to minimum and, when required, presented in boxes.

Derived from the structure of the material, the hypertext structure is also different. The W/I interface is based on a linear structure, where students can proceed just to the previous or the next topic, with no additional links or deeper levels of content, but with frame arrangements allowing for the information required to be presented all at once. On the contrary, the A/V interface allows students to proceed to any page within the hypertext; further levels are used such as additional pages presenting the graphical content required.

Prominence of titles and headers was an important issue in both designs, since these help student understanding and give some organisation to the material. Still some other components are different in each interface such as the range of colours used on each design –a larger, brighter combination for the imager design; the set of buttons on each screen; and the layout used in each screen. A zigzag arrangement of information was also chosen to provide a more playful environment for *Wholists*.

3.7 SUMMARY

The research strategy adopted in this phase of the research followed a 3-stage approach for dealing with cognitive individual differences. The first stage required to assess the extent of the differences as stated in objective four (O4) of the research. For this purpose, an extensive analysis of cognitive styles and learning styles was carried out that allowed the identification of a series of characteristics on which different models and classifications are based. Various examples of educational AH systems that incorporate cognitive and learning styles into their adaptive functionality were critically reviewed, as were a series of studies that have been carried out to investigate the effect that different variables have on learners with different style. The stable nature of cognitive styles as opposed to the variable character of learning styles was highlighted, and the case argued for adopting Riding and Cheema's model of cognitive style to synthesise the essential characteristics of the differences observed, and Peterson's VICS & ECSA-WA test to ascertain the students' cognitive style.

In the second stage, key cognitive characteristics of learners were identified and organised under Riding and Cheema's dimensions of analysis, which accomplishes objective five (O5) of the research.

In the final stage, some learning conditions that capitalise on the essential characteristics previously selected were outlined, which in turn helped to identify a series of adaptive variables and to outline an approach for the design of adaptive interfaces for Web-based learning materials. This relates to objective six (O6) of the research.

This chapter has also argued that while various educational AH systems have incorporated different techniques to cater for the individual style of their learners, most of them have focused on specific aspects such as content sequence, control strategy or mode of presentation. Conversely, the approach introduced would require the use of a series of adaptive variables and strategies in combination. Complex as this may result, the implementation of a multivariable approach would be possible from a technical point of view; the question would then be to what extent the proposed approach may enhance the learning experience of individual learners and/or improve their learning performance.

To validate the proposed approach for the development of adaptive interfaces for Web-based learning materials a prototype was developed. The design of LEARNINT is also detailed in this chapter, which corresponds to objective seven (O7) of the research.

LEARNINT has been used as a test vehicle to understand the extent of the implications of using cognitive characteristics for designing Web-based learning materials. The results of an initial study are discussed in the next Chapter.