
CHAPTER 1

INTRODUCTION

The Internet and the World Wide Web (**WWW**, **Web**) have opened new ways of learning for many people. Educational applications and learning materials available in one place can be used by learners from all over the world, and learning is increasingly changing from a “traditional cohort-based, classroom delivered, teaching driven model to an individual, computer-delivered, learning centred model” [MacKinnon and Brown, 2000, p.269]

To understand these changes, education has to be considered in its relation to global economic, social and cultural development; in so doing some drivers of change are readily identified such as greater access to education, flexible work practices, governmental policy, and the ubiquity of the Internet [UNESCO, 2004].

In the case of Higher Education (**HE**) the last decade has seen a significant increase in student numbers and with it greater student diversity, further pressure on resources, and requirements for improved flexibility in teaching and learning modes [Fry et al., 2003]. In efforts to meet these new and changing demands, Information and Communication Technologies (**ICT**) are expected to deliver increased outreach and economies of scale, as well as qualitative improvements such as greater individualisation of learning [UNESCO, 2004].

To meet these expectations, the use of ICT has to be grounded in sound educational approaches; by considering how students learn it is possible to design and embed ICT into teaching and learning with maximum effect. In this regard, several approaches have become well recognised such as behaviourism, instructional design and constructivism. Lately, constructivism has been particularly influential since its strong theoretical base offers great scope for exploiting the opportunities offered by ICT.

Constructivism states that knowledge is individually constructed through interacting with the world, thus learning rather than teaching is the central issue in this process [Papert, 1980; Boyle, 1997; Laurillard, 2002]. Part of moving to this learner-centred approach is recognising that each student approaches learning from their own perspective, unique experience and own understanding, which in the changing context

of HE represents a clear need for a more systematic approach to supporting student learning. ICT are therefore required to provide flexibility at the individual level, enabling pace, sequence, content and teaching strategy to better fit each student's learning goals. In particular, the Web is seen as a suitable environment for personalised learning where students can be uniquely identified, content can be specifically tailored, and progress can be individually monitored, supported, and assessed [Martinez & Bunderson, 2000].

The research reported here addresses the issues of adaptation and personalisation of the computer interface for Web-based, interactive learning materials. It is expected that providing adaptive, personal interfaces for learning materials will offer students an improved learning experience, one that suits their individual requirements.

1.1 PERSONAL LEARNING ENVIRONMENTS, COGNITIVE STYLES AND AFFECT

From the standpoint of constructivism, learners actively construct their own understanding, thus each learning experience is unique for each individual because people differ from one another. But, how do people differ? What individual characteristics do people have and how do those vary? What differences are useful, which ones are stable and which ones really have an impact on the interaction during learning situations?

There has been considerable research on the development of learning technologies to target individual differences and to adapt the learning experience to the particular requirements of its users and their environment. Technological approaches range from Intelligent Tutoring Systems (ITS) to a series of adaptive applications that have been introduced over the past few years. These adaptive systems are built around a series of models that generally include a domain model, a user model, and an interaction model. Changes in the system functionality are driven by the maintenance of a model of the user between sessions. Generally, information stored in the user model relates to their demographics, preferences, previous knowledge or behaviour [Brusilovsky, 2001]. A more sophisticated approach has to take into account the cognitive characteristics of its individual users in order to provide each student with a suitable learning experience [Cristea & De Bra, 2002].

Over the years the relevance of cognitive styles and learning styles for learning has been extensively explored. Learning styles are considered to cover a range of approaches to

learning that can vary for the individual when taking into account factors such as subject matter, mode of assessment or amount of time available. Cognitive styles, on the other hand, are considered more fundamental to the individual's personal and psychological makeup, "an individual's characteristic and consistent approach to organising and processing information" [Riding & Rayner, 1998, p. 8].

The initial assumption of this research work was that if cognitive styles were individual and non-changing, they could provide important elements for designing adaptive, personal interfaces. It was hypothesised that if the cognitive style of an individual was identified, suitable teaching strategies could be selected which would facilitate learning. In turn, these strategies would determine to a great extent the structuring and composition of the learning content presented to the user and, in the case of Web-based learning environments, the design of the interaction between the system and its users. The preliminary belief was thus that identification and use of cognitive styles combined with intelligent interfaces could facilitate the achievement of desired learning goals.

On the other hand, learning is increasingly understood as a complex interaction of structures and processes having both cognitive and affective components. Accordingly, in researching the issues of adaptation and personalisation of the computer interface for Web-based learning materials, affective factors become apparent and their relationship with the learners' cognitive style and learning performance was explored further.

1.2 RESEARCH AIM, SCOPE AND OBJECTIVES

If the aspirations of this research could be condensed into a single sentence, its main aim would be summarised as: "to develop the concept of adaptive interfaces for Web-based learning materials based on key characteristics of the learner's cognitive style, allowing the provision of personal learning environments to suit the individual learning needs of each student". The rationale, concepts and variables of such a concept are presented as a methodological approach for the inclusion of key characteristics of cognitive styles in the design of adaptive systems for learning.

The scope of this research is to present an approach to the development of adaptive interfaces that takes into account key characteristics of the learners. The approach defines a series of empirically validated adaptive variables based on fundamental characteristics of cognitive styles for the provision of adaptive interfaces. The research concerns the enhancement of the modelling dimensions underpinning the functionality

of adaptive hypermedia systems, and particularly the consideration of adaptive variables for the definition of the adaptation model, as well as key characteristics of learners for the user model.

While learning technology refers to the application of a wide range of ICT, this research is applicable to Web-based adaptive systems. A prototype has been developed to validate the proposed approach. With respect to the development of the prototype, the research is concerned with the learner experience and learning performance rather than system functionality for which it builds upon existing architectures for the design and development of adaptive hypermedia systems.

The research as a whole is grounded on sound educational approaches, and while different theoretical bases that relate to the issues of personalisation and development of learning content are considered, its main foundation is on the principles of constructivism.

The objectives that guide the research are to:

- O1: Identify driving issues and educational approaches behind personalisation of learning.
- O2: Critically analyse current work in the fields of personalisation and adaptive systems for learning.
- O3: Identify the relevance of using cognitive styles for the design of adaptive, Web-based systems for learning.
- O4: Assess the extent of individual differences under different classifications of cognitive styles.
- O5: Select and extract essential characteristics of the learners' cognitive style.
- O6: Present an approach to the design of adaptive interfaces for Web-based learning materials based on key cognitive characteristics of learners.
- O7: Develop a prototype to validate the proposed approach for the development of adaptive interfaces for Web-based learning materials.
- O8: Evaluate the prototype to gather evidence to support the proposed approach.
- O9: Identify further variables that may influence the interaction between learners and adaptive interfaces for Web-based learning materials.

O10: Propose a methodological approach for incorporating key characteristics of the learners in the modelling dimensions underpinning adaptive hypermedia systems for the provision of adaptive interfaces for Web-based learning materials.

1.3 RESEARCH METHODOLOGY AND APPROACH

As suggested by some researchers [Benyon, 1993; Cristea & De Bra, 2002], from the standpoint of the interaction between individual learners and computer-based learning materials, dealing with cognitive differences requires a 3-stage approach. First, it is required to assess the extent of the differences in order to identify what to measure and how to measure it. Once differences have been identified, their essential characteristics have to be selected and extracted. This should go through an iterative refinement process for achieving an efficiently working model. When the important features have been identified it is then necessary to accommodate these through a suitable design.

A research strategy has been observed through this project that follows the process outlined before. It entails a deductive approach to the relationship between theory and research, in which previous work in the field is used as the basis to guide empirical enquiry.

The first stage of the research strategy required an extensive review of different models and classifications of cognitive styles, together with a critical appraisal of various educational AH systems, some of which incorporate cognitive styles into their adaptive functionality. As a result, the case was argued for using Riding and Cheema's model of cognitive styles [Riding & Cheema, 1991] since it synthesises extensive previous research in the field. The model comprises two dimensions of analysis: the *Wholist – Analytic* and the *Verbaliser – Imager* styles; these respectively refer to the habitual way in which an individual processes information and to their habitual mode of representing information when thinking.

As part of the second stage of the methodological approach, key defining attributes of cognitive styles were identified and organised under Riding and Cheema's dimensions of analysis. Instructional conditions that capitalise on these characteristics were also outlined.

In the final stage, the identified characteristics of cognitive styles and their advantageous instructional conditions were used in combination to derive a series of variables for the design of adaptive interfaces for Web-based learning materials.

This research has also adopted a qualitative style that incorporates epistemological considerations from positivism in that causality can be inferred between particular events that are seen as occurring together in space and time [Bryman, 2004; Hayes, 2000]. This empirical stance has been useful to guide the iterative validation of the suggested approach for the design of adaptive interfaces -i.e. the iterative evaluation of LEARNINT.

An experimental research design was used for the collection and analysis of data to support the proposed approach for the development of adaptive interfaces for Web-based learning materials. A prototype called LEARNINT was used as a test vehicle in a within experimental design aimed at exploring the extent to which cognitive styles, user experience and learning performance interrelate under different interface conditions. The research method included a series of tasks that participants carried out using the LEARNINT system, self-completion questionnaires to register their perceptions about the interaction with the system, assessment tests to measure their learning performance, and the VICS&E-CSA test to determine their cognitive style. Throughout this process a strict ethical code of practice was observed

Results from the initial evaluation of LEARNINT suggested that learning performance seemed to be superior under interface conditions that elicit a positive affect in the learner. The term *Interface Affect* has been used in the research to refer to this affective reaction of the learner to a particular interface style.

These findings implied that the proposed design approach based on adaptive variables could facilitate more effective learning and enhance the learning experience. However, a number of issues were identified regarding the experimental design used, which in addition to the small number of participants determined the need to modify the experiment for the next iteration of the evaluation process. Moreover, given the fact that the concept of Interface Affect had been put forward, a number of associated issues such as the learner's affective reactions under different interface conditions needed to be investigated further.

It became apparent that the style of the interface used raises positive or negative affect towards the interaction with computer-based learning materials. In turn, affect was characterised as informing individuals about the pleasant or unpleasant nature of an event, indicating their estimated coping ability, shaping their ensuing behaviour, and contributing to build a framework used to assess and react in future situations.

The extended evaluation of LEARNINT aimed at validating the results obtained in the initial study and exploring the possible relationship between cognitive style, interface affect and learning performance under different interface conditions. LEARNINT was updated, as was the experimental design used.

A thorough analysis of the information gathered showed that most participants expressed more positive affect towards one of the interface styles available. Differences were also observed in terms of learning performance since the majority of the participants performed better in their preferred interface.

On the whole, the analysis of the data suggested that interface style does have an impact on the Interface Affect expressed by the participants, which in turn has an impact on their learning performance. Furthermore, detailed statistical analysis of the information gathered suggested that the adaptive variables underpinning the interface styles used in LEARNINT greatly contributed to the differences observed in users' reactions and performance.

To accommodate the adaptive variables previously derived and extend the functionality of LEARNINT, further implications for the design and development of educational adaptive applications have been identified. Building upon current approaches to the development of adaptive systems and using the Dexter model as a reference framework, a methodological approach has been put forward for the inclusion of key characteristics of the learners in the modelling dimensions underpinning adaptive hypermedia systems for the provision of adaptive interfaces for Web-based learning materials

A number of limitations of this research work have been identified and are discussed in this thesis, as are some suggestions for further research.

1.4 THESIS OUTLINE

This first Chapter provides an introduction to the whole research. It includes the research aim, scope and objectives, research methodology and approach, as well as the thesis outline.

Chapter two follows this introduction up and provides a characterisation of the driving issues and educational approaches behind personalisation of learning, which corresponds to objective one (O1) of the research. It also includes a critical analysis of existing research relevant to the thesis, including details about current approaches to

personalisation and adaptive systems for learning (O2). It finally puts forward the use of cognitive styles for the design of adaptive Web-based learning systems (O3).

According to the methodology outlined for the research, dealing with individual cognitive differences requires firstly to assess the extent of such differences (O4) then to extract its key characteristics (O5) in order to advance a suitable design approach. Chapter three details this process and presents a series of adaptive variables derived from it, which serve as the basis to propose an approach for the design of adaptive interfaces for Web-based learning materials (O6). In the final part of this Chapter the LEARNINT prototype, which was developed to satisfy objective seven (O7) of the research, is introduced.

Chapters four and five are dedicated to objectives eight (O8) and nine (O9) of the research. They present the evaluation studies carried out to gather evidential support for the proposed approach for the design of adaptive interfaces for Web-based learning materials. Results from the initial evaluation of LEARNINT are presented and discussed, in Chapter four, including the limitations of the experimental design used. Further research looking at emotion and Interface Affect issues is presented in Chapter five, as is the rationale behind the changes in the research design and the LEARNINT prototype.

Chapter six discusses in detail the results obtained through the empirical stage of the research. This Chapter consolidates the findings that emerged during the evaluation studies and discusses their implications for the design of adaptive interfaces for Web-based learning materials. Limitations of the empirical evaluation of LEARNINT are also discussed here.

A methodological approach for incorporating key cognitive characteristics of the learners in the modelling dimensions underpinning adaptive systems is put forward in Chapter seven (O10). Emerging issues in the field of adaptive systems related with the objectives of the research are also discussed in this Chapter.

Chapter eight summarises this research and critically discusses its contributions as well as its limitations and constraints. Some recommendations are included, as are suggestions for future work.