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# CHAPTER 8

## SUMMARY OF FINDINGS AND FUTURE WORK

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### 8.1 INTRODUCTION

This Chapter summarises the research carried out and discusses a number of issues raised by this thesis from several perspectives. The discussion begins by examining different sources of individual differences for learning, including their potential advantages for the provision of adaptive Web-based learning materials. Topics reviewed in the light of the work carried out include cognitive styles, learning styles, approaches to learning, cognition and emotion, as well as their impact on the interaction for learning and on the design and development of adaptive Web-based learning materials. Results from the experimental stages of the research are reviewed as is the LEARNINT approach. This Chapter also consolidates the material presented in the thesis by examining the findings and achievements of the research, as well as its limitations. Finally some suggestions are offered for further research.

### 8.2 DISCUSSION

This research effort started with the aim to develop the concept of adaptive interfaces for Web-based learning materials to allow the provision of learning environments to suit the learning needs of students at the individual level. This goal was mainly stirred by the high expectations placed on the use of ICT, and particularly of the Web, in terms of qualitative improvements and greater individualisation of learning, and also by the strong conviction that the use of such technologies need to be grounded in sound educational basis.

It has been argued that the learning process is not identical for all human beings. Rather, it seems that knowledge is individually constructed through the interaction with the world [Papert, 1980; Boyle, 1997, Laurillard, 2002]. Moreover, it appears that the physiological structures that govern learning allow the emergence of processes that emphasise some orientations over others [Kolb, 1984]. As a result, learners with

different characteristics will respond differently to each form of instruction. Thus, some of the benefits expected from looking at individual differences for learning include that:

- Since individual differences play an important role in learning and instruction, different instructional strategies will be more or less effective with certain learners.
- Awareness of individual differences can provide a better understanding of the difficulties that arise for certain learners in relation to specific learning environments.
- Learning performance may improve if the approaches for which each learner is likely to be successful are identified.
- Considering the role of individual differences in learning can be useful in directing the design and development of Web-based learning materials.

The research major assumption therefore was that it is possible and desirable to provide adaptive Web-based learning environments to accommodate differences among individuals in order to improve learning experience and performance.

However, since the research base in the field is inconsistent, support for this idea is less than definitive. In particular, it has been argued that since individuals differ in their general skills and aptitudes for learning, their abilities to perform different school-based or real-world learning tasks, their preferences and personality and other traits, the extent of such differences makes each person unique [Papert, 1980; Jonassen & Grabowski, 1993; Riding & Rayner, 1998]. As a result, the task of describing such variation can become impractical.

Consequently, the research sought an intermediate position whereby variation could be explained in terms of the combination of a relatively small number of dimensions. In doing so the task of identifying these variables and using them was seen as possible and potentially useful.

Differences were initially limited to the analysis of cognitive styles, and specifically to the identification of key characteristics that could impact the interaction between learners and Web-based learning materials. However, in the light of the work carried out other issues such as learning styles, approaches to learning and the relationship between cognition and emotion were also considered.

### **8.2.1 Cognitive Styles**

The broad range of individual differences spans from specific abilities to general styles. The list includes characteristics such as intelligence and mental abilities, personality, learning styles and cognitive styles among the more relevant. While all of them contribute to the learning process, some of these differences are very difficult to define or assess, and some others do not correlate with specific learning requirements or instructional approaches. Intelligence, for example, is a term at the same time vague and complex: "...we all share an understanding about what it means to be intelligent, but it has different meanings for each of us." [Jonassen & Grabowski, 1993; p. 5]. In addition, the sources of intelligence vary; the measures used to assess it range from processing speed and capacity of the brain, to information comprehension and reasoning [Riding & Rayner, 1998; Jonassen & Grabowski, 1993]; and, according to Jonassen & Grabowski [1993] there is no simple relationship between intelligence and instructional approaches. Something similar occurs with the concept of personality, which generally describes how individuals interact with their environment and especially with other people [Jonassen & Grabowski, 1993]. As with other sources of individual differences, there are difficulties in agreeing its constituting dimensions [Riding & Rayner, 1998; Jonassen & Grabowski, 1993].

Cognitive styles, on the other hand, describe how an individual interacts with their environment, extracts information from it, constructs and organises personal knowledge, and then applies that knowledge [Riding & Rayner, 1998; Jonassen & Grabowski, 1993]. Cognitive styles are considered to be an individual's stable approach to knowledge acquisition; therein lay their potential to provide significant basis for identifying appropriate learning and instructional approaches to suit the needs of each learner.

Relevant research on cognitive styles has produced a wide range of models, which however has not ended up in a widely accepted taxonomy. Nevertheless, underlying the distinctions made between classifications there is a general model of cognition that emphasises how information is perceived, processed, stored and put into practice. This fundamental understanding and the stable nature of cognitive style suggested that the aim of identifying key cognitive characteristics of learners to inform the design of adaptive interfaces for Web-based learning materials was viable.

### **8.2.2 Learning Styles, Approaches to Learning and Learning Strategies**

In addition to the concept of cognitive style, research was carried out regarding issues of learning styles, approaches to learning and learning strategies.

Evidence from previous research [including Riding & Rayner, 1998; Jonassen & Grabowski, 1993; 128; Diseth & Martinsen, 2003] indicating that learners achieve varied success in different types of learning activity and that their success on a particular task can, to some extent, be predicted by their cognitive style, endorse the view that style is a relatively fixed core characteristic of an individual. Yet, a number of researchers [Entwistle, 1988; Ramsden, 1988; Schmeck, 1988; Riding & Rayner, 1998; Diseth & Martinsen, 2003; Jonassen & Grabowski, 1993; Schmeck, 1988; Sadler-Smith & Smith, 2004] also maintain that individuals develop learning strategies to deal with learning tasks and contexts that are not initially compatible with their cognitive style. While the stability of style is emphasised, research nevertheless recognises that several strategies of learning and problem solving may be adopted as a response to environmental demands.

Models of learning style describe individual differences in the learning process related to the learners' perceptions of their own preferences [Riding & Rayner, 1998, Jonassen & Grabowski, 1993], suggesting that learning style is related to learning strategies and the approach each individual assumes towards learning.

While the distinction between cognitive styles and learning styles was early identified in the research, some relevant models and classifications of learning styles were also included in the initial analysis of significant cognitive characteristics of learners.

### **8.2.3 Cognition, Emotion and Interaction for Learning**

Recent developments in a range of disciplines such as neuroscience, psychology and cognitive science are transforming our understanding of how individuals really learn. Learning is increasingly understood as the result of a complex interaction between structures and processes internal and external to the learner, comprising affective and cognitive functions [Martin & Briggs, 1986; Martinez & Bunderson, 2000; Picard, et al., 2004]. Accordingly, some issues that were further investigated to support the research included:

- *Emotions and affect* – Emotions arise from encounters with events that are perceived as relevant for the individual. In these situations, affect is not perceived as

a feeling, the individual is rather aware of the pleasant or unpleasant nature of events [Fijda, 1993]; it is in this way that the notion of affect gives emotions their non-cognitive character.

- *Affect and thought processes* – Affect induces different kinds of thinking; positive affect broadens the thought process, whereas negative affect leads to closure to stimulation and selective attention [Fijda, 1993; Isen, 2000; Norman, 2002]. Affect also signals the state of the individual's estimated coping ability, which refers to a set of past events and related behaviours [Fijda, 1993]. Emotional experiences are thus objects of reflective judgements: past events help building a framework that influence the way individuals assess a particular situation, their affective reaction and their consequent behaviour.
- *Affect and computer interfaces for learning* – It has been observed that different interfaces evoke different reference contexts, which in turn raise positive or negative affect towards the interaction [Davis & Wiedenbeck, 2001]. When the interaction is for learning, learners will assess the current setting and select those learning strategies that they consider best to cope with the learning task. Developing and applying learning strategies is an extended process driven by a tendency to seek cues for the purpose of achieving success.

All these concepts considered suggest that certain elements of the interface style elicit a sense of familiarity with the learning environment. This judgement, being part of the emotional appraisal of the current situation, triggers an affective reaction towards the learning environment, which in turn impacts the kind of learning strategies each student puts into practice to cope with the learning task.

#### **8.2.4 The LEARNINT Approach**

While the distinction between cognitive style and learning style was clearly identified in the early stages of the research, a number of models and classifications of both learning styles and cognitive styles were included in the initial analysis of significant individual differences of learners. Key characteristics were identified and organised under Riding and Cheema's model of cognitive style dimensions [Riding & Cheema, 1991]. In turn, these defining attributes as well as a series of corresponding advantageous instructional conditions were used to derive a series of variables upon which adaptive interfaces for

Web-based learning materials could be designed. Based on these variables, a prototype was then built.

LEARNINT was used as a test vehicle to investigate the implications of using key cognitive characteristics of learners for the design of adaptive interfaces for Web-based learning materials. A relationship was clearly determined between the reaction of a student to the interface style (*Interface Affect*) and their learning performance, suggesting that for the majority of the students learning outcomes may improve if they experience positive affect towards the style of the interface being used. Conversely, no simple relationship was observed between cognitive style and Interface Affect or learning performance.

On the other hand, it was observed that the cognitive style of the learners that participated in the evaluation studies, as determined by the VICS & E-CSA-W test, was consistent. With just one exception, the students that participated in the initial and extended evaluations of LEARNINT were postgraduate students in science or engineering. When their scores in the two cognitive style dimensions were analysed in combination, the distribution of the participants was similar in both evaluation studies: the majority of the students were of *Analytic* style and a high proportion of them of *Imager* style (see Figure 6.1).

These results seem to suggest that the cognitive style test is informing research about a series of common characteristics in the way this particular group of students perceives and process information. Yet, the lack of a clear relationship between their cognitive style and Interface Affect or learning performance may indicate that the whole set of key characteristics of learners still need to be fully clarified.

While research and development relating to individual differences and personalisation of learning environments and instruction remains broadly focused on cognitive interests and related mechanisms for processing information, findings from the experimental stages of the research support the case for an integral approach including cognitive and affective factors. This is particularly true for the results suggesting that learning performance may improve when the interface style elicit positive affect, which support developments and related research emphasising that a key consideration in personalisation of Web-based learning materials involves understanding how emotional and cognitive processes interact during learning [Martinez & Bunderson, 2000].

The research has however acknowledged the need to carry out further work to clarify the nature of the relationship between cognitive styles, Interface Affect and learning performance. It has been suggested that the whole set of key characteristics of learners may include not just their cognitive style (how they process and organise information), but also their instructional preferences (predispositions towards particular learning formats) and learning strategies (conscious actions that students employ to deal with the demands of specific learning situations), as well as affective reactions.

Further work is also required to assess the learners' perceived familiarity with the style of the interface in use. While the scale proposed in the research certainly correlated with Interface Affect and showed acceptable internal reliability, familiarity was not statistically significant for learning performance.

A number of additional issues that may be worthwhile exploring further include:

- The dynamic interaction between style and approach to learning. Including arguments suggesting that style influences approach and approach determines learning outcomes [Jettmar & Nass, 2002, Diseth & Martinsen, 2003].
- The consistent adoption of habitual ways of dealing with a diversity of learning tasks across time and situations. Authors, such as Diseth & Martinsen [2003] argue that learning strategies are driven by a tendency to seek environmental cues for the purpose of achieving success.
- The learner's previous experience in terms of familiarity with the learning environment and earlier success in similar contexts.

### **8.2.5 Extending the Functionality of LEARNINT**

Findings from the research supported by previous work in the field endorse the use of the proposed adaptive variables for the development of adaptive interfaces for Web-based learning materials.

It has been suggested to extend the functionality of LEARNINT based not on stereotypes classifying the learners' cognitive style, but using variables and related instructional strategies that continually change in line with the interaction between the system and each individual learner. A methodological approach has been put forward, suggesting a learner model that evolves along time and interaction with each individual taking into account their behaviour, performance, expressed preferences and affective reactions. In turn, the domain model has to be organised around different learning tasks and media

formats, whereas the adaptation model has to use the system knowledge about the domain and about the current state of the learner model to determine the appropriate instructional strategies and interaction with the learner through the interface of the adaptive application.

In addition, a number of emerging issues have been discussed that need careful consideration for the design and development of educational AH systems, such as technological platforms, open learner models and the educational Semantic Web.

### **8.3 LIMITATIONS OF THE RESEARCH**

The thesis has contributed useful research to the field of personalisation of learning and particularly to educational AH systems, with specific emphasis on the design and development of adaptive interfaces for Web-based learning materials. However, there are some limitations of the research which need to be considered. These limitations mainly relate to the design and development of LEARNINT, to the empirical evaluations carried out and to the scope of the research; these issues are addressed below.

In terms of the development of the prototype, consideration has to be given to the fact that its main aim was to provide a proof of concept of the design approach proposed; as such, LEARNINT is only a partial implementation of a fully functional adaptive hypermedia system. Its initial scope was to primarily convey the main features of adaptive interfaces for Web-based learning materials and to investigate to which extent these related to the learners' experience and performance. While its design and development took into account the adaptive variables identified and the research and analysis previously carried out, as well as sound principles for the design and development of interactive systems for learning, there is the possibility that the interface styles did not fully put across all the features sought. Nonetheless, the qualitative feedback received from the participants indicated that differences in the design of the interfaces had been evident enough for them to clearly identify two different styles conveying the learning content presented. This was further supported by the quantitative results of the experiments in that most of the learners identified and preferred one interface style over the other.

A series of limitations were also identified relating to the empirical evaluations of LEARNINT (Chapter 6), which involve issues of completeness and level of confidence in the results.

In terms of the general scope of the research, it has to be noted that while Interface Affect has been characterised as the reaction of a student to the style of the interface, there is a need to further explore the concept in order not just to explain the results from the data collected, but also to understand how user preferences interact with style during learning situations and what the implications are for the design of adaptive interfaces for Web-based learning materials.

Also, there are some aspects relevant to the individual make of students that have not been considered; in particular that of collaboration for learning. For some individuals collaboration and interpersonal contact is an important element of the learning process; while for others the opportunity to interact with others is less important [Sadler-Smith & Smith, 2004].

## **8.4 CONCLUSIONS**

The main thrust of this thesis has been to develop the concept of adaptive interfaces for Web-based learning materials to allow the provision of learning environments to suit the learning needs of each individual learner.

One of the main issues contributing to its novelty include the empirical approach adopted since, until very recently [e.g. Brown et al., 2006], little research had been carried out investigating the impact of cognitive styles in learning outcomes using educational AH systems. Previous related work had mainly focused on modelling psychological constructs or adapting existing models to particular architectures. Few empirical evidence of its effectiveness has been made available.

The approach adopted in the research started with a thorough analysis of individual differences and the identification of its main constructs and its applicability to the design of adaptive interfaces for Web-based learning materials. A series of key cognitive characteristics were identified and a series of adaptive variables proposed and used to build the LEARNINT prototype. This also represents a novel aspect of the research since most adaptive AH systems that in the past have catered for the individual style of their learners have focused on specific features. Conversely, the approach introduced through LEARNINT impacts the various modelling dimensions underpinning adaptive applications.

The key contributions of this research are:

1. A series of variables for the design of adaptive interfaces for Web-based learning materials derived from an extensive analysis of key cognitive characteristics of learners and related instructional strategies.
2. The LEARNINT prototype, which provides a proof of concept of the design approach proposed. The prototype demonstrates the potential of an educational system based on key individual characteristics of the learners to improve learning experience and efficiency.
3. The prototype evaluation, which provides evidence to establish the validity of the design approach proposed. The results show that an efficient implementation of the model can be useful for providing adaptive interfaces for Web-based learning materials to improve the experience and learning performance of students.
4. A methodological approach for incorporating the proposed adaptive variables in the modelling dimensions underpinning educational AH systems in order to provide adaptive interfaces for Web-based learning materials.

In terms of the design and development of adaptive interfaces for Web-based learning materials, the main findings of the research are:

1. Learning performance may improve if learners experience positive affect towards the style of the interface being used. The term *Interface Affect* has been used in the research to refer to the learner's affective reaction to a particular interface style.
2. Cognitive style does not significantly influence Interface Affect or learning performance. This finding, supported by previous research in the field suggests that assessing the cognitive style of learners once is not sufficient for providing truly adaptive interfaces.
3. Features of the interface style that have a major impact on Interface Affect and learning performance include mode of presentation, learning content, content structure, layout and navigation.
4. Educational AH systems need to support continuous changes in the user model and to adapt the interaction accordingly. While the cognitive style of the learner may contribute to initialising their user model, the adaptive functionality of the system may benefit from using adaptive variables and instructional strategies.

Since the approaches and mechanisms for personalising learning and particularly for providing adaptive Web-based learning materials are currently subject of much debate among researchers from many diverse subject areas, the achievements and findings of this piece of work provide useful evidence of the benefits, constraints and further challenges that faces this area of research.

## **8.5 FURTHER RESEARCH**

To complete this thesis a few suggestions for further research are made. A range of topics have been covered in these pages, spanning from learning theories and individual differences to affective learning and technical aspects of educational AH systems. There is therefore much that could be investigated further both practically and theoretically. To delimit the discussion, some topics have been identified and discussed in detail in Chapter 7, which offer the most potential for expansion:

1. An immediate area of further development for the work carried out to date is to extent the functionality of LEARNINT and to develop a fully functional system based on the methodological approach outlined in Chapter 7. Various possibilities exist for this purpose, including the development of a completely new system with all the features and functionality expected. Alternatively, it would be possible to work in collaboration with other research groups, such as AHA! or MOT, and to explore the possibility of contributing to their developments to implement the approach proposed in the thesis. In either case, consideration has to be given to various aspects such as the time required for completing the system, as well as the advantages and disadvantages of building upon existing developments.
2. Given that the learner model represents a fundamental component in the provision of adaptive learning environments, an area of research that offers significant potential for further development is the implementation of open and interactive models. Current approaches to personalisation include various ways of collecting and inferring information about the user and a significant amount of research is being carried out aiming at giving the learner a more active role. While some of the advantages for making the learner model more accessible include improving students' engagement and reflection, as well as enhancing the quality of the model, there is an ongoing discussion about the implications for the design, development and implementation of overt learner models. Some of these considerations include what information to make available, how to convey the learner model in an

accessible and easy to use manner, to what extent changes in the learner model affect the adaptive behaviour of the system, what technical approaches are suitable, and what are the ethical and practical implications of this process, to mention but just a few issues.

3. Over the past few years the concept of the Semantic Web has gained relevance among the research community. Some topics of particular relevance for the advancement of adaptive educational applications towards the envisaged Web include the provision and use of semantic markup and the availability of suitable ontologies. Implications of markup for educational AH applications include the location and re-use of learning objects that meet the learning needs of individual users; also, to what extent such markup complies with suitable specifications and standards in order to facilitate their semantic manipulation. In turn, the implications of ontologies refer to the extent to which subject domain models and learner models of adaptive applications can take the form of ontologies. On the whole, the vision for the Educational Semantic Web relies on interoperability of learning content, knowledge and functional content based on extensive expression of semantics and standardised communication processes. There is plenty of potential for further research in this field.
4. On the technical side, there are some current approaches aiming at improving the design and responsiveness of interactive Web-based applications. An example of such approaches that has been explored in the thesis is AJAX, a development model that combines a number of existing technologies to provide asynchronous, incremental updates of the user interface without reloading the entire browser page. This approach could greatly benefit the adaptive presentation of learning content based on the continuous interaction between the system and each individual learner.

There is an obvious need for more research and development in the fields of individual differences and personalisation and adaptation of Web-based learning. The aim of such activity should be to gain a better understanding of how individual differences impact the interaction for learning. Such an understanding will, it is hoped, lead to the provision of learning environments that better suit the needs and preferences of each student. It is also hoped that this research has usefully contributed to the debate.