Chapter III
Can Cognitive Style Predict How Individuals Use Web-Based Learning Environments?

Martin Graff
University of Glamorgan, UK

ABSTRACT

This chapter considers the question of whether Web-based learning environments can be employed to effectively facilitative learning. Several questions are considered around this issue, principally whether variations in hypertext architecture, and individual differences in information processing are salient factors for consideration. Furthermore, whether the effectiveness of learning depends precisely upon how learning is defined. Finally, differences in hypertext navigational strategies are assessed in terms of whether these can be predicted by individual differences in cognitive style. The chapter ends by concluding that the research on Web-based instructional systems is to some extent promising, although the field of cognitive style is diverse, and realistic predictions regarding the use of this construct in instructional design is, as yet, tenuous.

INTRODUCTION

One of the salient features of web-based learning environments is that they can provide an explicit structure to instructional material, which should ultimately facilitate the learning process. For example, such structures can be designed to explicitly indicate the conceptual links between related information. The following chapter assesses the degree to which this theoretical position can be supported by the extant literature. More precisely, this chapter reviews the literature on how web-based or hypertext-learning systems have been employed in an educational context. We will consider issues such as the most facilitative hypertext architecture for assisting the learning process. Later in the chapter the evidence on the extent to which cognitive style mediates the effects
of architecture are reviewed. Finally, evidence will be assessed regarding the way in which users navigate hypertext and how this may influence their comprehending of its structure.

BACKGROUND

Web-based learning environments are structured around hypertext systems, which allow conceptually related pieces of information to be connected or linked. Information on one page in the system can be linked to a related piece of information contained in a separate page. Such systems are user driven, in as much as individuals can choose to be ‘transported’ or moved within the system to pages containing related information. Furthermore, web-based or hypertext systems can be structured in a variety of ways, and the way in which the system is structured is referred to as the system architecture. Typical architectures found in the literature are ‘linear’, where pages of information are linked sequentially, rather like they are in a book; ‘hierarchical’ where superordinate information is contained in pages higher up the system, and linked to more detailed information further down in the structure and ‘relational’, which is similar to the hierarchical architecture, although this structure also contains lateral links between conceptually related information at the more detailed level.

This chapter considers the effectiveness of learning from web-based systems, and it is appropriate at this stage to consider the term ‘learning’, and the way in which it has been applied in the literature. Perhaps one of the most expedient notions of learning to consider in this respect is that offered by Bloom’s Taxonomy of levels of learning (Bloom, 1968). In essence, Bloom advocated that learning could be arranged at different levels ranging from basic knowledge or recall, up to a more sophisticated type of learning manifest in evaluation or synthesis of material. The notion that learning can be applied at different levels is important to consider as we review the extent to which learning may be facilitated by web-based learning environments.

WEB-BASED LEARNING AND HYPERTEXT ARCHITECTURE

A useful starting point would be to question whether using different hypertext structures differentially affect learning performance. The earlier studies considering this question seem to suggest that mixed or relational web-based or hypertext systems appear to be the most facilitative.

For instance in a study by Mohageg (1982) the issue of whether question answering performance would vary following delivery of learning materials via three different web structures or architectures was considered. The architectures used in this study were hierarchical, where the learning material was constructed such that more general information was contained higher up the structure, and more specific information lower down; network, where the information was structured in a complex system of links; and mixed which was a combination of the other two structures. The findings indicated that learning performance was poorest in the network architecture condition. However, there were no differences in learning performance in the other conditions. The interpretation of this finding was that as the mixed condition featured more links than the other conditions, this may have increased the learners’ facility for learning.

McDonald and Stevenson (1998) employed 30 undergraduate and postgraduate students in their study of web-based learning. They also used three hypertext architectures, which were hierarchical (as described above), non-linear (in which the information was constructed in a type of network) and mixed (hierarchical with lateral links). After using one of the three systems, participants answered ten questions on information
they had read in the learning system. The findings revealed that those student participants who had used the mixed system found information quicker than participants in the other conditions, which is possibly due to the fact that the mixed architecture made it easier for the users to understand the overall structure.

The above studies sought to measure learning using tests of recall, which is synonymous with basic knowledge or recall at the lower level of Bloom’s Taxonomy of Learning (Bloom, 1968). However, as outlined earlier, learning also takes place at a deeper level, which could be said to involve an appreciation of the interrelationships between the various concepts and procedures in a particular subject domain. This more sophisticated approach to learning might necessitate comprehending how related concepts within a subject domain, may be arranged or constructed into a unified whole. This issue is considered with respect to web-based learning, in the following section.

Learning at a Deeper Level

In one study, Shapiro (1998) used an essay question to investigate how effectively learners showed an appreciation of the overall structure of the information contained within a web-based learning system. Three different architectures were employed in this study, which were hierarchical with some lateral links, unstructured, which had the same links as the hierarchical, but with no specific information about the structure, and linear where the material was presented sequentially, one step at a time. Seventy-two participants were asked to write an essay which required them to integrate the material they had learned from reading information from one of the web architectures. Essays were rated on four criteria which were integration of material in the essay, how well the participant understood the topic about which they were writing, the clarity of the essay and the overall quality of the essay. On all of these criteria, it was found that participants in the unstructured hypertext condition scored higher than those in the other conditions. The interpretation of this finding was that the lack of any explicit information in this condition required a deeper level of processing of the information in order for participants to understand it, and this resulted in a higher level of performance.

Concept Maps

Concept maps provide a visual representation of the interrelationships among concepts or pieces of knowledge relating to a particular subject domain. This idea was pioneered by Joseph Novak in the 1960s, and it is suggested that the technique may facilitate an individual’s learning of how the finer details contributing to a wider body of knowledge are integrated. It is also conceivable that concept maps may also be employed to facilitate a user’s understanding of the interrelationships between smaller, more detailed pieces of information presented in web-based learning environments.

Shapiro (1998) in the study outlined above, compared also the concept mapping performance of participants, assigned to one of the three hypertext learning environments outlined. Participants were required to recall the structure of the hypertext web by producing drawings, one measure of which was amount of detail present. Participants in the linear condition included less detail in their concept maps than participants in the hierarchical and unstructured conditions. This finding was explained in terms of participants in the hierarchical and unstructured conditions visiting the same pages in the structure more times than the participants in the linear condition, thus the amount of exposure to the information, led to differences in the amount of detail recalled. Shapiro also found that participants in the hierarchical and unstructured conditions produced concept maps which reflected the actual links in these structures, and it therefore seems that the
Can Cognitive Style Predict How Individuals Use Web-Based Learning Environments?

A slight variation to this finding was reported by McNamara, Hardy and Hirtle (1989). They found that despite using non-hierarchical hypertext environments, their participants still produced map representations which tended to be hierarchical. They explain this finding in terms of certain types of information being mentally organised in a hierarchical manner. Such a mental organisation facilitates effective recall of the information.

We now move on to consider the different ways in which individuals navigate or move around hypertext environments, and assess how this may be used to provide information on the affect it has on an individual’s ability to apprehend its structure. The reasoning behind this notion is that the route an individual takes through an environment is likely to influence their representation of that space. Indeed Maglio and Matlock (1999) found that the way in which individuals move around in hypertext affects the ways in which they think about it. From their interview data, they suggest that people view hypertext as a type of physical space in which they move around. Their participants remembered landmarks and routes, and also the key information they found while navigating. In addition to this they found that participants relied on personal routines, similar to the types of routines individuals employ when travelling from one point to another. The suggestion is that the way in which an individual navigates will affect their mental representation of the hypertext. In the next section the types of navigational strategies which have been identified in the literature are examined. In the literature, the terms ‘navigation’ and ‘browsing’ are sometimes used interchangeably with regard to moving around in hypertext. The broad distinction would appear to be that browsing is considered to be a more casual non-goal related task, whereas navigating is more purposely directed towards some final end. Nevertheless, both terms refer to how we move around a hypertext system.

Navigational Strategies

Batra, Bishu and Donohue (1993) identified differences in navigational behaviour according to the hypertext architecture to which users were assigned. The two architectures they employed in their study were hierarchical and hypertorus (pages arranged in a rectangular pattern). They also looked at the effect of each type of architecture on participants’ ability to answer ten questions, the answers to which could be found in the hypertext. Their results suggested that the hypertorus structure generated more exploratory browsing behaviour, but despite this the hierarchical structure made it easier for participants to locate information. However, it is easy to interpret the findings as being attributable to the number of links in each architecture.

In their study Canter, Rivers and Storrs (1985) categorised navigational strategies as being related to the function each strategy serves for the user of the hypertext. These strategies included pathiness, where users follow long linear paths; loopiness, where users navigate around the hypertext in circles; ringiness, which are small loops or circles and spikeiness, where users follow paths to dead ends. The researchers also examined the number of pages within the hypertext users visited, and number of different pages visited, and the ratio of different pages visited to the total number of pages visited. From this information, they devised five distinct navigational strategies, which were scanning (covering a large area without depth), browsing (following a path until a goal is reached), searching (striving to find an explicit goal), exploring (finding out the extent of the information system) and wandering (purposeless and unstructured globe-trotting). The authors also concluded that these navigational strategies apart from wandering, have a function in navigating hypertext. Scanning and exploring are used to get an overview of the hypertext, whereas browsing is following a train of thought through the hyper-
text. All in all, this study provides a useful way of categorising navigational behaviour.

Despite the fact that the above studies provide comprehensive information regarding the relative effectiveness of different hypertext architectures on learning, none of the studies reviewed so far has considered individual differences in the ways in which various users engage with hypertext. Because it specifically refers to individual differences in information processing the construct of cognitive style is pertinent to consider in assessing how effectively individuals learn from hypertext.

**COGNITIVE STYLE, HYPERTEXT AND LEARNING**

Cognitive style can be defined as a variation in the ways in which individuals process information, in terms of differences in perceiving, remembering, recalling and applying this information. Various cognitive style constructs have been proposed by various researchers, for example reflective-impulsive (Kagan, Rosman, Day, Albert and Phillips, 1964), convergent-divergent (Guildford, 1959), leveller-sharpeners (Holzman and Klein, 1954) and serialist-holist (Pask, 1972). All of these style constructs are based on the notion that different style types exist at opposite ends of a continuum. The style type field dependent-independent which developed from the work of Herman Witkin is one of the most extensively used models of cognitive style. Field dependence-independence is defined in terms of whether individuals perceive entities as separate units, (field independent) or as complete wholes (field dependent). There is also evidence to suggest that there are differences in the ways in which field dependent and field independent individuals learn (Witkin, Moore, Goodenough and Cox, 1977). Field independent learners are able to see a degree of structure in what they learn, whereas field dependent learners rely more upon being provided with a structure externally.

Theoretically, a highly structured hypertext instructional architecture will be of greater benefit to field dependent learners, because this will provide an organisational aid to their learning. Conversely, a poorly structured learning environment where a degree of organisation would need to be provided by the learner would be less beneficial to field dependent learners, although in such an unstructured environment, field independent learners would suffer no debilitation in learning, because of their superior capacity for imposing structure on the material they are attempting to learn. However, the empirical evidence reviewed in the following does not necessarily support this reasoning.

For example, Lin and Davidson-Shivers (1996) assessed verbal recall in a group of 139 undergraduate students, following a period of time using one of five hypertext architectures. The architectures corresponded to linear, hierarchical, hierarchical-associative, associative and random, and all of the architectures contained the same information. The participants were also assessed using the Group Embedded Figures Test (GEFT) designed to measure field dependence-independence (Witkin, Oltman, Raskin, and Karp, 1971). The results of this study revealed that participants who were more field independent as indicated by their higher GEFT scores, outperformed participants who were assessed by the GEFT as being more field dependent. In addition to this, field independent users displayed more favourable attitudes to using the hypertext than field dependent participants. The researchers explained the results by suggesting that field independent learners are more self motivated and have greater expectations of achievement.

Consistent with the previous study, a further investigation assessing the differences between field dependent and field independent learners’ ability to answer questions following a period of time browsing a hypertext architecture, again revealed that field dependent participants performed less well than field dependents (Korthauer and Koubek, 1994). In this study the learners were
Can Cognitive Style Predict How Individuals Use Web-Based Learning Environments?

experienced with the hypertext document they used. The findings are explained by the fact that the existing knowledge of the field dependent learners and the way in which these learners attempted to represent the information, conflicted with the more explicitly structured hypertext, thus affecting their learning.

However, one possible drawback with the above studies, is that the GEFT has been found to correlate with standard tests of spatial intelligence (McKenna, 1984, 1990). Accordingly, another possible interpretation of the above studies is that field independent learners possessed greater intelligence, and this accounted for their superior performance rather than any differences in the strategies they employ in organising the information they learn.

Accordingly, there is a need to consider potential differences in learning from hypertext employing a cognitive style measure independent of spatial intelligence. Melara (1996) employed forty participants who were students of computer science, maths or engineering and required them to complete Kolb’s Learning Style Inventory. This instrument identified participants as possessing either a reflective or active style. Following this participants were assigned to one of two hypertext architecture conditions, which were either hierarchical or network in structure. The design of the network structure was such that it linked together related concepts in order to form a web, and the task of the participants was to answer ten questions on the information featured in the hypertext. The results revealed no differences between the participants of different learning styles in each condition, however the results were approaching significance with superior performance from participants in the hierarchical condition. Furthermore, individuals with active and reflective styles displayed superior performance when using the hierarchical architecture. In essence the results merely show that a difference exists between the two hypertext structures, although style seemed to have no effect. One further difference was that the participants in the hierarchical architecture condition took significantly longer to complete the task, than participants in the network condition, which seems to be a more likely explanation for the superior performance of participants in this condition.

Learning Measured by Essay Questions

In an extension to the studies described above, Graff (2003a) looked at whether the way in which learning was assessed made a difference to the effect of matching different hypertext architecture conditions to the cognitive style of the learner. This study employed three hypertext architectures, which were linear, hierarchical and relational, with each representing a way in which the information to be learned was arranged. Cognitive style was measured using the Cognitive Styles Analysis (Riding, 1991), which identifies cognitive style in a way similar to the Group Embedded Figures Test (Witkin et al, 1971), but uses the label wholist for field dependent and analytic for field independent. Essay scores were measured by length and amount of detail included. The results indicated that in the relational architecture condition, intermediates (i.e. individuals between wholist and analytic styles) achieved superior scores.

The findings reviewed so far appear to indicate that cognitive style does have an impact on the degree to which individuals learn from hypertext, and therefore need to be considered in the design of web-based instructional systems. However, the findings from the above studies are somewhat perplexing as they derive from an array of style measures, and therefore more research is required, with a view to unifying and consolidating different measures of style.

We now move on to analyse how the application of style research can be applied to slightly more complex cognitive tasks performed within the parameters of hypertext.
Graff (2002a, 2005a) assessed differences in the types of concept maps produced by learners, and whether the types of maps could be predicted from measures of cognitive style. In one study 55 participants were assigned to one of three hyper-text architecture conditions which were linear, hierarchical or relational, and were instructed to recall information and produce maps of the hyper-text used (Graff, 2005a). In this study cognitive style was measured with the analysis-intuition measure of cognitive style (Allinson and Hayes, 1996), and the results revealed that analysts scored highest in the hierarchical condition, intermediates scored highest in the relational condition and intuitives scored highest in the linear condition. In terms of assessment of the concept map density (the degree to which users were able to integrate the concepts in the hypertext), participants using the hierarchical condition produced the least dense maps, with little difference between the relational and linear architectures. The higher density scores which users in the relational architecture condition produced was explained by the fact that the intricate relational architecture encouraged participants to produce dense maps purely because of the impression that this architecture gave them. The finding differs from that of Shapiro (1998) as here no differences in density scores were found between participants performing in different architectures. However, in the study by Graff (2005a), no differences in maps were found between individuals possessing different cognitive styles. In terms of assessment of map complexity, (how representative the map was of the architecture) the results revealed that participants performing in the relational architecture condition produced the most complex maps, with participants in the hierarchical condition producing the least complex maps. These results were explained by the fact that there were differences in perceived ease of use by participants in each architecture condition. The rather complex array of findings presented here provide no real evidence that cognitive style is a factor in predicting differences in concept map production.

Hypertext Segmentation and Overview Provision

When considering hypertext design, two further considerations need to be addressed. Firstly, the degree to which the hypertext should be segmented, in other words whether it should be designed with long scrolling pages, or whether the pages should be segmented and topics which are conceptually related be connected via hyperlinks. Secondly, whether the provision of an overview of the hypertext provides any advantage in guiding the user through the structure. Indeed, Dee-Lucas and Larkin (1995) discovered that the provision of a diagrammatic overview of the hypertext system made it easier for users by directing them to significant information within the system. Similarly, Hsu and Schwen (2003) compared the effects of structural cues derived from single and multiple metaphors in the design of hypermedia documents. Fifty-four undergraduate students were required to perform selected information searching tasks, and the findings indicated that the provision of metaphorical cues helped participants to find a greater number of accurate answers and do so in a shorter period of time.

However, it is entirely possible that an individual’s cognitive style could influence the degree to which segmentation and provision of an overview is useful. An investigation of this issue, Graff (2003b) employed 50 participants who browsed one of two hypertext architectures containing information on psychological ethics, and also completed the Cognitive Styles Analysis (Riding, 1991). The differences between the architectures was in terms of the degree of segmentation, with one being more segmented (required less scrolling of pages) than the other. Furthermore, half the participants were provided with an overview of the architecture, and the other half received no overview. After spending a period of time brows-
ing one of the two hypertext systems, participants were requested to answer questions regarding their understanding of the material featured in the hypertext. Both cognitive style and degree of segmentation influenced the degree to which participants learned from each architecture. More specifically, analytics displayed superior learning performance in the less segmented architecture, whereas wholists showed superior performance in the more segmented architecture. However, the provision of an overview of the system had no effect here.

**Cognitive Style and Hypertext Navigation**

The final question to be considered in this chapter is whether cognitive style can predict differences in the ways in which individuals navigate hypertext, and several studies on this issue are considered here. Firstly, Ellis Ford and Wood (1992) investigated this issue employing postgraduate student participants and who completed a Study Preferences Questionnaire (SPQ) which was a non standardised test developed by the authors of the study, and which measured holist and serialist study strategies, presumably conceptually similar to field dependent and field independent respectively. Participants were provided with navigation tools for using the hypertext, which were: a self-orientating global concept map, keyword index menus and a backtracking facility, and the subject matter of the hypertext was the European Single Market. The 40 participants used the hypertext, and were then required to answer several questions which required both factual recall and also integration of information from different parts of the hypertext. Their findings revealed that participants with a holist approach tended to make more use of the maps provided, whereas participants with a serialist strategy used the index menu.

In a further study, Chen and Ford (1998) employed 20 postgraduate students who used a hypertext system in order to attempt to learn about artificial intelligence. Using the Cognitive Styles Analysis to test style they discovered that wholists made greater use of a menu system for navigation, whereas analytics were more likely to use the backward and forward buttons on the browser software they were using. It must be said that the sample size in this study was small, and accordingly, it is unlikely that the results can be generalised from the findings.

The above studies however, tell us more about the user’s typical selection of hypertext navigational aids, and it is also relevant to examine navigation of hypertext in terms of the routes users take to move through the system.

In a study employing 60 participants, who used a structured hypertext and completed the Embedded Figures Test, Stanton and Stammers (1990) found that field dependent participants used bottom-up navigational strategies, progressing from the more basic information upwards, whereas field independent users tended to use top down strategies, which was viewing the most important information first. This finding is rather perplexing and seems contrary to the reasoning that field dependent users would be able to apprehend the structure of the whole hypertext, and therefore use a top-down strategy, whereas the opposite would be the case for field independent users. What was also contrary to what might have been predicted was the fact that field independent individuals viewed fewer pages than field dependent individuals, whereas the more likely finding would have been that as field dependent learners should have been able to gain an overview more easily, they would have viewed fewer pages.

Verheije, Stoutjesdijk and Beishuizen (1996), performed a study where navigation was assessed by requesting participants to search for information in a hypertext. They identified style by using the Dutch Inventory of Learning Styles which identifies individuals as deep or surface processors (Vermunt and Van Rijswijk, 1987). The findings revealed that different strategies were employed...
by individuals with different styles, more precisely that those identified as deep processors used a more global approach to navigate the text, whereas surface processors adopted a more step by step approach.

The final study considered (Graff, 2005b) employed two groups of participants, who were assigned to either a hierarchical or a relational hypertext architecture and allowed ten minutes to read information contained in the hypertext. Participants were told in advance that they would be expected to answer questions on the information they read, and hypertext navigational patterns were measured by using various indices, including the number of pages visited and the proportion of pages visited to pages revisited. Cognitive style was measured using the Cognitive Styles Analysis (Riding, 1991) which also reveals the extent to which individuals display imager or verbaliser styles. Variations were found between imagers and verbalisers, with the latter visiting more pages in the hierarchical architecture, and the former visiting more pages in the relational architecture. This preliminary evidence is somewhat encouraging in as much as it would appear to suggest that individuals with different cognitive styles do exhibit different navigational strategies.

**CONCLUSION**

This chapter has examined much of the evidence on the effectiveness of using hypertext or web-based learning systems as a medium of instruction. The general conclusion which can be drawn here is that the most facilitative hypertext architecture for

*Figure 1. Model of performance in using hypertext, determined by cognitive style mediated by architecture design*
effective learning is hierarchical in structure with lateral links, although to some extent it appears that cognitive style also influences the effectiveness of the hypertext architecture employed, and this is illustrated in the model shown in Figure 1. For example, cognitive style may to some extent determine how effective a particular architecture is to an individual for learning. Furthermore, the manner in which an individual navigates hypertext also influences his/her ability to understand its structure, and this is because the route followed has an effect on the individual’s mental representation of the hypertext. It is possible then that the route followed by an individual browsing hypertext could have an influence on the effectiveness with which they learn.

From the literature, it is clear, that numerous research questions regarding use of hypertext and cognitive style remain. More precisely, further research should pursue an attempt to investigate learning at a deeper level. As mentioned learning in many previous studies has been measured in a relatively simplistic way, and studies should now focus on attempts to assess learning in more realistic situations. While a few studies have sought to investigate the navigational strategies of users, further research should attempt to investigate this in relation to users’ cognitive style. Finally, in the literature, definitions of the term cognitive style appear fragmented, with little agreement on how the term may be properly operationalised. Accordingly, attempts to consolidate the construct under a single definition are now well overdue. Regardless of the pressing need for further work in the area, the initial conclusion indicates cognitive style to be a pertinent factor for consideration in the design and implementation of instructional systems. The evidence presented here, although mixed and rather unsettled at present, is nevertheless promising, and cognitive style ultimately has implications for the design of hypertext instructional systems.

REFERENCES


Graff, M. G. (2003a). Assessing learning from hypertext: An individual differences perspec-
Can Cognitive Style Predict How Individuals Use Web-Based Learning Environments?


Can Cognitive Style Predict How Individuals Use Web-Based Learning Environments?


