Individual Differences: Implications for Web-based Learning Design

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In the past ten years the Web has attracted many educators for purposes of teaching and learning. The main advantage of the Web lies in its non-linear interaction. That is, students can have more control over their learning paths. However, this freedom of control may cause, for some students problems such as disorientation, cognitive overload and control problems. To investigate these problems researchers have shifted there focus towards finding how is web-based learning used by learners with different characteristics and styles. In this paper, we outline the findings of some research on individual differences in the context of web-based learning. We also address how web-based learning systems can be adapted to learners' needs and styles. And then we suggest an adaptive web-based learning model, based on the analysis of findings obtained from these studies.

Individual differences, web-based learning, instructional strategies, education computer, learners' needs, learning style

INTRODUCTION

As a new delivery system, web-based learning is a unique hypermedia instructional program, which utilizes the World Wide Web (WWW) resources to create meaningful learning (Khan, 1997). One of the main features of web-based learning is that it allows learners flexibility to interact with each other at anytime and anywhere through synchronous and asynchronous modes. That is, it allows for self-directed learning.

Another important feature is the non-linearity where individuals have the freedom to choose their learning paths allowing them to have more control over their learning. These features and many others have increased the popularity of the WWW as a way of delivering instruction (Shih and Gamon, 2001). However, with this expansion of the use of the Web in education, educators should be more concerned with examining its effectiveness because instruction is not merely displaying information; rather it requires an integrated fit that considers the content, individual differences of learners and the delivery method to achieve success (Alexander, 1995; Martindale and Ahern, 2001).

Borgman *et al*. (1995) have claimed that investigating individual differences will allow educators both to make the transition to new innovative interfaces and to bring the systems to the users rather than the other way around. Therefore, designing appropriate hypermedia learning environments requires an understanding of the learners. Understanding their characteristics that might affect how they interact with a particular learning environment. Such characteristics may include the amount of prior knowledge of the learning domain, cognitive style, achievement motivation, age, gender, and other characteristics. Once a learner's profile is determined, hypermedia learning can be easily adapted in a way that best suits that learner.

A large body of research has attempted to define which individual differences actually influence hypermedia learning. In this paper we review some studies that investigated two types of individual differences, cognitive styles and prior knowledge. We outline and analyse the findings of these studies. Based on our analysis we suggest a web-based learning model that is adaptable to learners' needs and preferences.

COGNITIVE STYLE

Cognitive style is defined as an individual's preferred and habitual approach to organizing and representing information (Riding and Rayner, 1998). Field dependence versus field independence has emerged as one of the most widely investigated dimensions of cognitive styles in education, because it reflects how well a learner is able to perceive and restructure information based on the use of salient cues and field arrangement (Weller *et al*, 1994).

Witkin *et al*. (1977) used the term, field independence, to describe individuals who are individualistic, internally directed and accept ideas through analysis. On the other hand, field dependent individuals prefer working in groups, are externally directed, influenced by salient features and they accept ideas as presented. Research shows that field independent learners outperform field dependent learners in various conventional and web-based learning settings due to their different characteristics aforementioned (Ford and Chen, 2000).

In the past decade, many studies have examined the significance of cognitive style in hypermedia learning systems. Some of these studies looked at relationships between:

a) structure of hypermedia documents and cognitive styles (Chang, 1995),

b) cognitive style, performance, and navigational style (Ford and Chen, 2000), and

c) cognitive styles and linear and non-linear learning (Liu and Reed, 1995; Reed and Oughton, 1997).

Findings of these studies showed that learners with different cognitive styles react differently in non-linear interaction, which is the main feature of hypermedia programmes.

NON-LINEARITY

Non-linearity is a basic feature in hypermedia learning environments. This feature allows the learner to jump freely from one idea to another, without concern for a predetermined order or sequence. However, for some students especially field dependent students, giving such freedom might cause some problems such as disorientation, learner control and cognitive overload problems. In the following section, we discuss these problems in details and then we offer some solutions in the form of an adaptive web-based learning model.

Disorientation Problem

As we have mentioned earlier a hypermedia system is a very rich and flexible environment for knowledge representation. Research shows, due to this flexibility for representing knowledge and interconnections between the information, that field dependent learners are more likely to get disoriented during navigation in hyperspace, especially if there are no clear signposts as to where they are and where to go next.

Wang, Hawk, and Tenopir (2000) examined users' interaction with the Web. The *Embedded Figures Test* (EFT) was applied to determine students' cognitive styles as either field dependent or field independent. Their results revealed that field dependent individuals might experience more difficulty in navigating on the Web and might get confused more easily than those with a strong field independence tendency.

Furthermore, Palmquist and Kim (2000) investigated the effect of cognitive style on hypermedia learning. The *Group Embedded Figure Test* (GEFT) was administered to identify subjects' cognitive styles. They found that field dependent students tended to follow links prescribed by the designers and experienced more disorientation problems. As a result, they suggested that field dependent learners, especially when novices, might need special attention from the interface designers. Similar results were obtained from a study conducted by Chen and Ford (1998), in which a hypermedia program was presented with on-linear structure to give students an introduction to artificial intelligence. Riding's *Cognitive Style Analysis* (CSA) was administered in order to identify participants' levels of field dependence. The results indicated that field independent students found the structure of the hypermedia program clear. On the other hand, field dependent students experienced more disorientation problems.

It could be inferred, on the one hand, that field independents tend to take an active approach, apply their own organization on the information presented and are able to extract the relevant cues that are necessary for completion of a task. On the other hand, field dependent students tend to take a passive approach where they prefer guidance and attend to most salient cues regardless of their relevance (Chou and Lin, 1997). That is probably why they appeared to experience more disorientation problems. Once again, this suggests that field dependent learners need to be provided with instructional guidance, which can direct them to the relevant information and reduce disorientation.

Learner Control Problem

Learner control is another difficulty that faces field dependent learners in non-linear learning environments. Learner control is the amount of control an individual can exert in an instructional situation (Rasmussen and Davidson-Shivers, 1998).

Yoon (1994) conducted a study to investigate the effect of instructional control strategies and cognitive styles on students' learning outcomes. Eighty-six elementary school students were asked to learn from a computer-based instruction program. The results showed that field independent learners, who had a higher ability to engage in independent learning with analytical thought, performed better in the learner control version. On the other hand, field dependent learners, who were relatively passive and less to learn independently, performed better with the program control version.

Similarly, Ford and Chen (2000) examined student learning in a hypermedia system designed with learner control features that taught the design of Web pages with HTML. Riding's CSA was used to identify students' cognitive styles, they found no significant correlation between field dependent and field independent students and their learning outcomes. However, field dependent and field independent students preferred to use different subject categories. Field dependent students preferred to learn HTML with examples. On the other hand, field independent students preferred to see the detailed description of each HTML command.

Similar findings were also obtained by Liu and Reed (1995), who examined the different learning strategies used by thirty-three international college students in a hypermedia instructional program. The GEFT was employed to determine students as field dependent, field fixed, and field independent cognitive styles. They used a hypermedia program to teach English to international students in which learners could choose different presentation formats for supporting information about vocabulary words they were instructed to learn. They found that both field dependent and field independent students did equally well on an English vocabulary test. However, they used different types of media within the hypermedia learning system. Field independent students used more relationship options of words, while field dependent students used more video context options of words.

These studies show that field dependent individuals might gain benefit from hypermedia learning systems when less learner control and more guidance are provided. On the other hand, relatively, field independent individuals enjoy independent learning in hypermedia systems provided with high levels of learner control. These findings support what Jonassen and Grabowski (1993) concluded that field dependent individuals are influenced by structure per se while field independent individuals are less affected and often impose their own structure on it.

Cognitive Overload Problem

Cognitive overload is a serious problem that affects students learning in hypermedia learning systems. This problem emerges from the freedom of navigation that hypermedia systems offer. This freedom of navigation means confusion especially to field dependent learners. Their attention may be diverted from content and relationships as they attend to navigational decision making and disorientation may be experienced resulting in more cognitive overload. This problem also may be compounded by the vast quantities of easily accessible information, much of which may only be peripherally relevant (Paolucci, 1998).

PRIOR KNOWLEDGE

Prior knowledge is another important variable that is related to hypermedia learning systems. Significant literature review generally indicates that prior knowledge can account for a high level of variance in most learning situations (Tobias, 1994; Yates and Chandler, 1991) Individuals' prior knowledge in hypermedia learning includes previous understanding in the content area and levels of system experience appropriate to the program.

There are a number of issues related to prior knowledge within the context of web-based learning that need to be examined. One of these issues is learner control and cognitive style. Yoon (1994) found that field dependent students with low prior knowledge can facilitate their learning in program control treatment, and field independent students with low prior knowledge can improve their performance in learner control treatment whereas these strategies did not affect students with high prior knowledge. These findings echoed what Witkin, *et al.* (1977) suggested that field dependent learners perform optimally when given guidance that emphasizes key information and draws attention to necessary cues. Field independent learners are more individualistic and rule-oriented. Because field dependent students have greater difficulty imposing organization on an unstructured environment, Witkin, *et al.* theorize that field dependent and field independent learners may perform equally well when learning materials are highly organized.

Another issue pertinent to prior knowledge is navigation structure of hypermedia learning. Shin, Schallert and Savenye (1994) found that young students with high prior knowledge achieved similar scores under both a hierarchical structure, and a network structure, and managed their instruction time more efficiently, whereas low prior knowledge students achieved higher scores under the hierarchical structure than under the network structure, and finished their lesson more quickly under the hierarchical structure. In addition, they found that advisement was helpful in preventing disorientation in the network structure. Perhaps students who possess high prior knowledge are relatively capable of setting their learning paths by themselves in hypermedia programs with network structure. On the contrary, students with low prior knowledge seem to prefer to have a fixed path to follow in linear learning programs.

Further, McDonald and Stevenson (1998) studied the interaction between student's prior knowledge and their navigation behaviours while searching a text adapted to hierarchical, non-linear, and mixed structure hypertexts. The subjects were divided into high knowledgeable and low knowledgeable participants according to their knowledge of the particular subject matter, which was a psychology text.

The researchers studied the number of nodes opened, number of repeated nodes and completion time subjects needed to answer questions by searching through the text. Findings indicated that participants with high knowledge opened less nodes in mixed structure than in the hierarchical and non-linear structure and completed the tasks faster and performed better than the low knowledgeable participants. Perhaps, this may be due to the fact that high knowledgeable participants may experience fewer navigation problems because their greater grasp of the conceptual structure of the subject matter could enable them to navigate easily and find the relevant information on the Web without getting lost (McDonald and Stevenson, 1998).

ADAPTIVE WEB-BASED LEARNING SYSTEM

As discussed earlier, field dependent students and low prior knowledge students seem to meet more problems in non-linear learning within web-based learning environments. They may need special attention from instructional designers. A solution to this problem is developing adaptive web-based learning systems, shown in Figure 1, that tailor to individual users by taking into account their characteristics and learning patterns. This issue will be further discussed next.

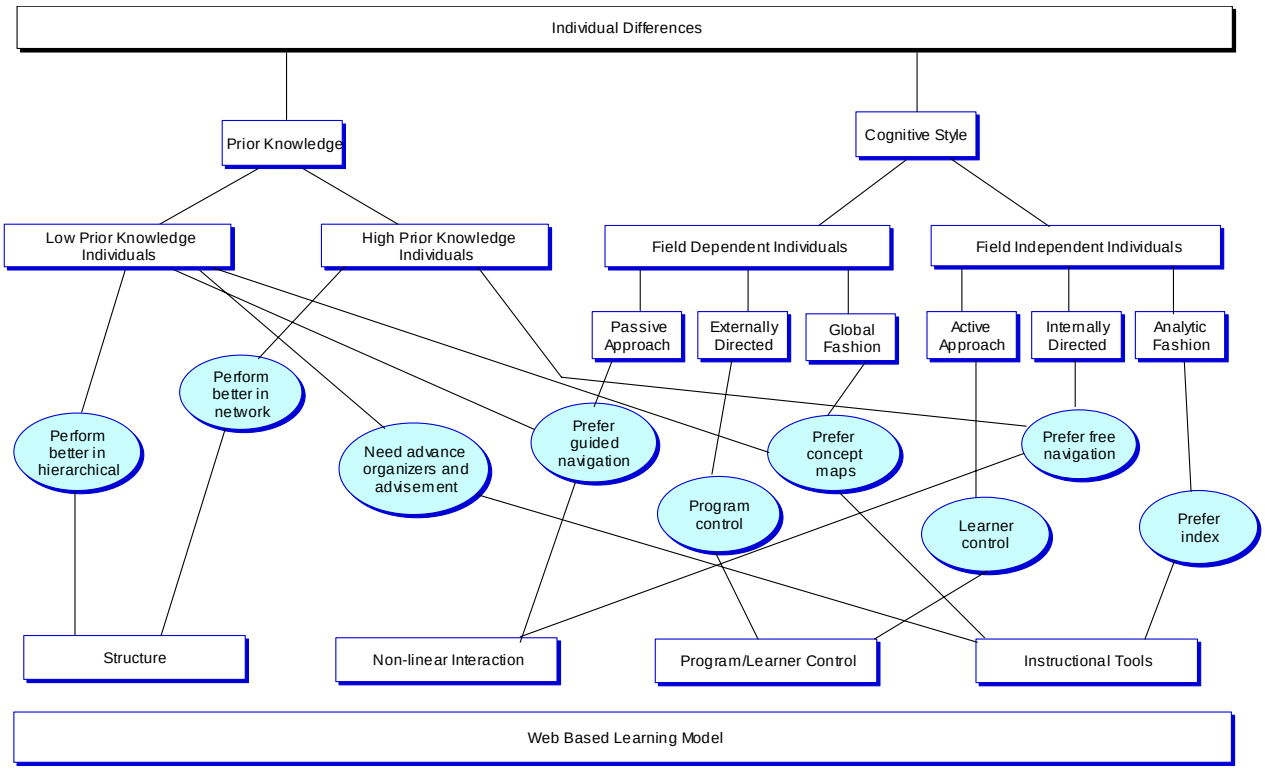

Figure 1. Adaptive web-based learning model

Adaptive Learner Control

In terms of learner control features, previous research has indicated that field independent learners prefer to have control over the system whereas field dependent learners were more comfortable with the program control (Hedberg and McNamara, 1989). However, it is possible to design hypermedia-learning systems for both field independent and field dependent learners with adaptive learner control. An adaptive learning system provides options that will allow both field dependent and field independent learners to feel comfortable with their interaction with learning programs. Since field dependent learners are externally directed, influenced by salient features, accept ideas as presented, and get decisions from others (Jonassen and Grabowski, 1993), the learner control features in the adaptive learning system should be adjusted for them by a) providing maps for orientation, b) visual material, and c) suggesting a route with instructional

cues. In contrast, as field independent learners are internally directed, individualistic, and represent concepts through analysis (Jonassen and Grabowski, 1993), providing different navigation tools in the design will help them locate specific information and exert more control over the program.

Adaptive Navigation Support

As indicated by previous studies, field dependent students experienced more disorientation problems towards non-linear learning. In this situation, several techniques can be applied to the design to minimize disorientation problems, some of these techniques might include: highlighting the context, graphic visualizations, links hiding and annotated links.

Highlighting the context

Highlighting the context is a possible approach to reduce the disorientation problems that field dependent learners might meet. Use of appropriate font sizes and colours may facilitate them to identify the part of the information being explored and the relative position in context.

Graphic visualizations

Graphic visualizations are also another possible solution to disorientation problems (Nielsen, 1995). Maps or hierarchical diagrams can be used in hypermedia learning systems to show current locations.

Links hiding

The idea of links hiding is to limit the navigation space and reduce the cognitive load by hiding all links to the nodes that the student is not expected to learn. There are two kinds of these links: links to not-ready-to-be-learned nodes and links to the nodes that are outside the users' current goal. In 'pure annotation' mode these links were not annotated. In 'hiding' mode these links are hidden: they are removed from any menus and its position in the menus is occupied by the next visible links. Hiding links can help field dependent students identify easily which concepts and nodes should be visible at the given moment, and which should not (Brusilovsky, 1998).

Annotated links

Adaptive annotation is the augmentation of links with some form of comments, which inform the user about the current state of the nodes behind the annotated links (Da Silva, Van Durm, and Duval, 1998). There are several types of annotation. Among these annotation techniques, history-based annotation can work as a means to help field dependent students to know whether a link has been visited or not. Perquisite-based annotation can be applied to provide field dependent students with information on the background relevant to the concept being learned.

ADAPTIVE COGNITIVE OVERLOAD

Another problem students experienced in non-linear learning systems is cognitive overload. In order for field dependent learners to cope with such a cognitive load there are several techniques the interface designer can use. For example, cognitive load can be reduced by: a) reducing the number of options at any one point in the program; b) by encouraging users to externalise their thinking, by use, for example, of text annotations and place-marking; c) by 'hiding' program options not likely to be needed by most users; d) by providing strong visual clues to aid navigation; and, e) by reducing the number of hypermedia links between information nodes (Oren, 1990).

PRIOR KNOWLEDGE AND ADAPTIVE HYPERMEDIA LEARNING SYSTEM

It appears from the aforementioned research on prior knowledge that the learners with salient prior knowledge are able to employ highly effective acquisition strategies such as organization, chunking and elaboration, and so become able to process and assimilate relatively high levels of information input without suffering cognitive overload effects. In addition, more knowledgeable users may experience fewer navigation problems because their greater grasp of the conceptual structure of the subject matter could enable them to impose structure on the Web (McDonald and Stevenson, 1998).

On the other hand, less knowledgeable learners in hypermedia learning environments may experience disorientation and cognitive overload (Last *et al*, 2001). This may be due to the fact that they are unfamiliar with the subject matter of the text, so they cannot rely on prior knowledge to help them structure the text. Besides that they are unable to use effective acquisition strategies to process high levels of information. Therefore, students with low prior knowledge should be helped to use what they know to help themselves process information effectively. One way to do so is to provide advance organizers that activate existing knowledge (Shapiro, 1999). Another approach is to allow students to share knowledge in small-group discussions prior to beginning a new and possibly unfamiliar task. Advance organizers have been used successfully to augment the learning outcome for students engaged in traditional text-based learning and those engaged in hypermedia-assisted learning. Prior research has shown that this effect may occur because the organizer provides cues to prior knowledge, which is then used as an elaborative tool for the new information.

CONCLUSION

Research shows that web-based learning systems may not be always suitable for all learners as a learning environment. Educators and instructional designers must be aware of student's individual differences such as cognitive styles and prior knowledge possessed. Some learners, such as field dependent learners and learners with low prior knowledge, may need more attention and support from instructional designers, while other learners may be able to work independently in web-based learning systems. Therefore, adaptability is important in the design of web-based learning systems to allow a variety of individuals to use and enjoy the system.

In an attempt to achieve that and based on the findings of previous research, this paper has presented a learning model (Figure 1), which illustrates the effects of individual differences, namely cognitive styles and prior knowledge on web-based learning and the relationships between key ideas. This model can be applied for the design of adaptive web-based learning systems that can be tailored to match with needs and preferences of both field dependent and field independent students. Further research should elaborate and apply the suggested model to explore further the relationships between such individual differences and web-based learning systems. Consequently, it will be interesting to find whether or not adaptive web-based learning systems applying the model suggested by this paper can accommodate students' individual differences.

REFERENCES

Alexander, S. (1995). Teaching and learning on the World Wide Web. *AUSWEB 1995* [Online] http://www.scu.edu.au/ausweb95/papers/education2/alexander [2003, October 9]

Borgman, C.L. Gallagher, A.L. Hirsch, S.G. and Walter, V.A. (1995). Children's searching behaviours on browsing and keyword online catalogs: The science library catalog. *Journal of the American Society for Information Science*. 46 (9), 663-684.

Brusilovsky, P. (1998). Adaptive educational systems on the world-wide-web: a review of available technologies Proceedings of Workshop "WWW-Based Tutoring" at 4th international Conference on Intelligent Tutoring System (ITS'98), San Antonio TX. [Online] http://www-aml.cs.umass.edu/~stern/webits/itsworkshop/brusilovsky.html. [2003, October 23]

Chang, C.T. (1995). *A study of hypertext document structure and individual differences: Effects on learning performance.* Unpublished PhD Dissertation. Urbana–Champaign: University of Illinois.

Chen, S. and Ford, N. (1998). Modeling user navigation behaviours in a hypermedia-based learning system: An individual differences approach. *Knowledge Organization*, 25(3), 67-78.

Chou, C. and Lin, H. (1997). Navigation maps in a computer-networked hypertext learning system. Paper presented at the Annual Meeting of the *Association for Educational Communications and Technology,* Albuquerque, No (ED 403 882).

Da Silva, P., Van Durm, R.. Duval, H. and Olivie, H. (1998). Adaptive Navigational Facilities in Educational Hypermedia. *Proceedings of the ninth ACM conference on Hypertext and hypermedia.* Pennsylvania, United States. [Online] http://portal.acm.org/citation.cfm?id=276664. [2003, November 5]

Ford, N. and Chen, S.Y. (2000). Individual differences, hypermedia navigation and learning: An empirical study. *Journal of Educational Multimedia and Hypermedia*, 9 (4), 281–312.

Hedberg, J.G. and McNamara, S.E. (1989). The human-technology interface: Designing for open and distance learning. *Educational Media International,* 26 (2), 73-81.

Jonassen, D.H. and Grabowski, B. (1993). *Individual differences and instruction.* New York: Allen and Bacon.

Khan, B.H. (1997). *Web-based instruction*. Englewood Cliffs, NJ: Educational Technology.

Last, D.A., O'Donnell, A.M. and Kelly, A.E. (2001). The effects of prior knowledge and goal strength on the use of hypertext. *Journal of Educational Multimedia and Hypermedia*, 10 (1), 3–25.

Liu, M. and Reed, W.M. (1995). The effect of hypermedia assisted instruction on second-language learning through a semantic-network-based approach. *Journal of Educational Computing Research*, 12 (2), 159–175.

Martindale, T. and Ahern, T.C. (2001). The effects of three web-based delivery models on undergraduate college student achievement. *International Journal of Educational Telecommunication*, 7 (4), 379-392.

McDonald, S. and Stevenson, R.J. (1998). Effects of text structure and prior knowledge of the learner on navigation in hypertext. *Human Factors*, 40(1), 18-27.

Nielsen, J. (1995). *Multimedia and hypertext: The Internet and beyond*. Cambridge, MA: Academic Press.

Paolucci, R. (1998). The effect of cognitive style and knowledge structure on performance using a hypermedia learning system. *Journal of Educational Multimedia and Hypermedia*, 7(2/3), 123-150.

Palmquist, R.A. and Kim, K.S. (2000). Cognitive style and on-line database search experience as predictors of Web search performance. *Journal of the American Society for Information Science*, 51 (6), 558–566.

Oren, T. (1990). Cognitive load in hypermedia: Designing for the exploratory learner. In S. Ambron and K. Hooper (eds.) *Learning with interactive multimedia,* (pp.126-136). Washington:Microsoft Press,

Rasmussen, K. and Davidson-Shivers, G. (1998). Hypermedia and learning styles: Can performance be influenced*? Journal of Educational Multimedia and Hypermedia*, 7, 291-308.

Reed, W.M. and Oughton, J.M. (1997). Computer experience and interval based hypermedia navigation. *Journal of Research on Computing in Education*, 30, 38–52.

Riding R. and Rayner S. (1998). *Cognitive styles and learning strategies: Understanding style differences in learning and behaviour*. London: David Fulton.

Shapiro. A, (1999). The relationship between prior knowledge and interactive overviews during hypermedia-aided learning. *Journal of Educational Computing Research*, 20(2), 143-167

Shin, E.C., Schallert, D.L. and Savenye, W. C. (1994). Effects of learner control, advisement, and prior knowledge on young students' learning in a hypertext environment. *Educational Technology Research and Development*, 42 (1), 33-47.

Shih, C. and Gamon, J. (2001). Web-based learning: Relationships among students motivation, attitude, learning styles and achievement. *Journal of Agricultural Education*, 42 (4), 12-20.

Tobias, S. (1994). Interest, prior knowledge, and learning. *Review of Educational Research,* 64 (1), 37-54.

Wang, P., Hawk, W.B. and Tenopir, C. (2000). Users' interaction with World Wide Web resources: An exploratory study using a holistic approach. *Information processing and Management*, 36, 229–251.

Weller, H G. Repman, J and Rooze G E (1994). The relationship of learning, behaviour, and cognitive styles in hypermedia-based instruction: implications for design of HBI. *Computers in the Schools* 10, 401–420.

Witkin, H.A., Moore, C.A., Goodenough, D.R. and Cox, P.W. (1977). Field dependent and field independent cognitive styles and their educational implications. *Review of Educational Research*, 47, 1-64.

Yoon, G.S. (1994). The effect of instructional control, cognitive style, and prior knowledge on learning of computer-assisted instruction. *Journal of Educational Technology Systems*, 22, 357–370.

Yates, G. and Chandler, M. (1991). The cognitive psychology of knowledge: Basic research findings and educational implications. *Australian Journal of Education,* 35 (2), 131-153.