Developing a cognitive framework for examining educational hypermedia

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Abstract

The rise in the use of the World Wide Web in teaching and learning has elevated the use of hypermedia as a mode of information accessing. Many researchers have theorised that hypermedia offers potential benefits to learning and a number of empirical studies have attempted to investigate such claims. In the main, these studies have compared the learning effects of hypermedia with that of print-based text. Some studies report superior learning effects (Jonassen, 1988; Frey & Simonson, 1994; Liu & Reed, 1995), whilst others have found advantages for text (Shneiderman, 1987; Reihm, 1996). Clearly the jury is still out about the extent to which the non-linearity of hypermedia provides a suitable learning medium for all or the majority of students.

Part of the conundrum is that there is not yet a well-developed theory of educational hypermedia (Rouet & Levonen, 1996; Dillon & Gabbard, 1998; Ford & Chen, 2002). In order that this theory develop further more empirical work is necessary. A critical aspect of this empirical work will be research that informs about the ways in which learners engage with hypermedia courseware and the reasons behind their engagement decisions. One line of inquiry might be to examine the cognitive aspects of these engagements. This paper discusses some of the key cognitive dimensions of educational hypermedia and attempts to draw together a framework with which to examine its effects on learning.

Background

In recent years, the emergence of digital documents has progressed from word-processed text, through stand-alone hypermedia, to the World Wide Web. When directed at educational purposes the technologies are collectively referred to educational hypermedia. Some commentators and educators (eg Landow, 1992; Dryden, 1994) have predicted major shifts in paradigm to the manner in which we understand the learning experience and the educational process as a result of these technologies. The promise of hypermedia has been touted as having ‘the potential to become a significant application area: equalling or perhaps exceeding that of word processing, spreadsheets and general database application’ (Begoray, 1990, p. 121). The nonlinear nature of hypermedia and assumptions about its educational value appear to underlie much of this argument.

Yet after a decade of research, other authors (Mcknight, Dillon & Richardson, 1991, 1996; Dillon & Gabbard, 2000) suggest that such strong claims are short of supporting evidence from studies of learners. Dillon (1996) argues that in the last decade of empirical evidence much has been generally assumed about hypermedia, but rarely demonstrated; ‘that the unmistakeable advantages of hypertext have rung hollow’ (p. 26). The lack of a general theory of hypermedia learning and a tendency to overlook the lessons learned from user studies of previous technologies are considered major reasons for these claims not being realised (Dillon & Gabbard, 1998). Rouet and Levonen (1996) agree that a major drawback of current research and understanding of hypermedia is its lack of a thorough theoretical foundation. That there is neither a
general theory of hypermedia, nor a model of the cognitive processes involved in interacting with hypermedia. Thus, there remains a large gap between theories of knowledge or discourse and the actual capacities of hypermedia systems.

The next section of this paper discusses the evolution of educational hypermedia, provides a definition, and explores some of the cognitive dimensions of the learning experiences associated with it. The final part builds from these dimensions a cognitive framework that might assist in further empirical research.

**Hypermedia**

*From Hypertext to Hypermedia*

The term’s hypertext and hypermedia are often used interchangeably. There is, however, a clear distinction between the two terms. Hypertext is an idea that can have its historical roots traced back to Vannevar Bush (1945). Bush with his emphasis on the role of association in cognition dreamed of a technology that would allow us to deal with an exponentially growing knowledge base by quickly facilitating the selecting, retrieving and arranging of data. It has been the advent of the computer that has allowed for the realisation of this idea. The concept of hypertext is a simple one, that of nodes of text being linked together. In hypertext information is organised as a network in which nodes are text chunks (e.g., list of items, paragraphs, pages) and links are relationships between the nodes, virtually any kind of relationship that can be imagined between two text passages (Rouet, Levonen, Dillon & Spiro, 1996). Thus, hypertext systems have been proposed as a means of facilitating the interactions between readers and texts (Chen, 1995; Dede, 1996; Duchastel, 1990).

In contrast, hypermedia can be thought of as an extension of hypertext in which the technologies of sound, graphics, animation and video have been added to that of text (Lai & Waugh, 1995). As a result, the notion of a node is extended beyond that of just containing textual information to one in which it includes sound, graphics, animation and video. The term hypermedia therefore accounts for the inclusion of these additional technologies. It is this more inclusive definition more accurately portrays the current application of these technologies in education. At its core hypermedia still has a text base, however, sound, graphics, animation and video are increasingly supplementing this. Collectively these technologies are referred to as hyper(media) reflecting the move beyond just hyper(text).

In this paper the focus is on the “hyper” element and less concerned with any particular kind of media. That is, the focus is on the way learners’ employ the “hyper” to facilitate their learning. So, the term hypermedia is used throughout as the more general term referring to information systems that offer hyper structuring, regardless of whether they include media other than text.

**A Definition of Hypermedia**

According to Tricot, Pierre-Demarchy & Boussarghini,(2000) hypermedia are documents or organised collections of documents. They consider a hypermedia document to be structured material that enables the user to ‘build sense’. More specifically then, hypermedia are electronic documents where the communication channel can be audio, visual or both; the code used can be linguistic, iconic or analogical (eg sounds, pictures, dynamic pictures); and the structure can be linear or
nonlinear. This definition provides a richer meaning of document than that associated with its paper based form. It is this richer concept of a document that leads to claims about its educational potential.

So, what are the claims being made about hypermedia that make it attractive for learning? Firstly, that hypermedia presents a new way to interact with media that differs from reading standard linear media (e.g., textbooks, diagrams and charts). For example, within a textbook the text is typically presented in a linear form, in which there is a single way to progress through the text, starting at the beginning and reading to the end. Secondly, that within hypermedia, information can be represented in a semantic network where multiple related sections of media are connected to one another (Foltz, 1996). Users may browse through the sections of media, jumping from one node to another. This permits the reader to select a path through the media that is most relevant to their interest. The concept of user selected pathways in hypermedia to retrieve and read information has caused a great deal of interest, particularly within the education community.

**Educational Hypermedia**

Many different perspective’s are emerging as to what educational hypermedia is and what it can do in education. There is a lack of consensus in this area, a situation due to the novelty of the technology and to its continuing transformation as technical possibilities continue to expand. These perspective’s can be illustrated from the literature. Some see hypertext and its extension hypermedia as a new CBI (Computer-based Instruction) authoring environment (Park, 1991), whilst others see a new type of CBI application emerging - hypermedia assisted instruction (HAI) or learning (Heller, 1990). Others see hypermedia as an ideal knowledge representation format that allows for generative or adaptive learning (Dede, 1988; Jonassen, 1986,1988); a powerful environment for exploratory learning for ill-structured, advanced knowledge domains or literacy education (Spiro & Jehng, 1990; Spiro, Feltovich, Jacobsen & Coulson, 1991); or a platform for multidisciplinary learning in the increasingly complex and growing field of science (Davenport & Cronin, 1990; Marchionini & Shneiderman, 1988).

*Hypermedia and learning*

Learning with the use of computers has been a growing aspect of education for more than two decades. In more recent times, and with the advent of the World Wide Web, applications have developed which utilise web browsers as the underlying production and delivery engine. The earliest entries into computer based learning were usually written using programming languages and constructed in the main by computer programmers. The pervasive nature of web browser technology, the underlying universally adopted Hypertext Markup Language (HTML) and software that enables the lay person to develop browser screens without any knowledge of HTML has led to a vast array of web-based products including educational products.

Hypermedia is a form of information access which is highly attractive to educational users because, on the surface at least, it leaves them in full control of that access while at the same time making it extremely easy. Hypermedia provides “*learning environments that promote the active, personal exploration of information for both comprehension and information*” (Welsh, 1995, p. 275). Thus, as a learning context, it
is seen as turning control over to the learner, a construct considered central to effective learning. Hypermedia as such espouses a very constructivist (Von Glaserfield, 1987) approach to learning: a view of learning emphasising active and interpretative knowledge acquisition, as individuals integrate and extend their knowledge in an effort to maintain its viability.

Much of the research into the use of hypermedia in education has focused on the capability of hypermedia for flexible information organisation and retrieval, interface design, or mixed media. The use of hypermedia as a tool for mediating the nature of the cognitive interactions that occur between learners and the computer has been less thoroughly explored (Yang, 2002). In addition, not much attention has been given to analysing the cognitive processes that go on in learner’s interactions with the technology. Therefore, further empirical studies that focus on learners’ interactions with hypermedia as a way of better understanding better the cognitive dimensions are needed. Such studies will require the development of frameworks that take account of the cognitive dimensions. Two aspects that would seem to be central to any such frameworks are the cognitive styles of individual learners and the cognitive dimensions of learner interactions with hypermedia.

The cognitive style of learners
In the past decade many studies have reported that individual differences had significant effects on student learning using hypermedia systems. Gender difference (Ford and Miller, 1996), system experience (Hölscher & Strubel, 2000), and cognitive styles (Durffesne & Turcotte, 1997; Shih & Gamon, 1999). Chen and Macredie (2002) argue that among these differences cognitive styles are seen to play an important role in the development of hypermedia-based learning. They consider cognitive style to be important because they refer to users’ information-processing habits, representing individual user’s typical modes of perceiving, thinking, remembering, and problem solving. Therefore, any framework that is used to develop research into the cognitive dimensions of learner interaction with hypermedia ought to take account of the cognitive styles of the learner.

Chen & Macredie (2002) propose a learning model, developed from evidence from previous research, which illustrates how cognitive style influences student learning in hypermedia systems. The model draws upon the concept of field dependence originated in studies on perception by Witkin and Asch (1948), Witkin (1950), and Witkin and Moore (1974). These studies revealed that individuals were different, but individually consistent, in their preferred modes of processing information. Witkin and Moore (1974) used the term Field Independence, to describe individuals who were said to rely on an internal and vestibular frame of reference, and Field Dependence, to describe individuals who rely on external and visual frames of reference.

After reviewing the literature and undertaking empirical research Chen & Macredie (2002) concluded that the evidence suggests that non-linear learning may be more suitable to field independent learners. In contrast, field dependent learners, who rely on external references and prefer structure, may have more difficulties with non-linear learning and still prefer a linear format. A tabular representation of their learning model (see Table 1 below) indicates the relationships between the characteristics and learning patterns of field dependent and field independent individuals.
### Table 1: Cognitive Model of Hypermedia Learning
- (derived from the characteristics and learning patterns of field dependent and field independent individuals identified by Chen and Macredie (2002)).

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Field Dependent</th>
<th>Field Independent</th>
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<tbody>
<tr>
<td>Learning Approach</td>
<td>Passive</td>
<td>Active</td>
</tr>
<tr>
<td>Navigation Preference</td>
<td>Guided</td>
<td>Free</td>
</tr>
<tr>
<td>Processing Information Tools</td>
<td>Global Maps</td>
<td>Analytical Indexes</td>
</tr>
<tr>
<td>Learner Control</td>
<td>Guided</td>
<td>Independent</td>
</tr>
</tbody>
</table>

According to Chen and Macredie (2002) the empirical evidence shows that field dependent learners adopt a passive approach to their learning in which they look for and follow any structure provided in the learning. As a consequence they prefer a hypermedia system that provides navigational guidance. In contrast, field independent learners adopt an active approach to their learning and prefer freedom of navigation. Field dependent learners adopt a global approach to information processing in which they rely on maps of the learning with which to build ‘entire perceptual fields’ (p.12) that guide them in their learning. This is in contrast to the field independent learners who prefer an index and other tools that assist them to locate information, whilst affording them the independence to choose how they might proceed with their learning.

The findings from this research indicates that close attention needs to be paid to how hypermedia systems can accommodate different learning preferences. It indicates that different kinds of learners need to draw upon the cognitive aspects of hypermedia systems in different ways. As a result it seems crucial that any hypermedia system ought to provide the cognitive tools to accommodate different kinds of learners. For example, it would be useful to provide maps of the learning for field dependent learners as well as providing an index for field independent learners. Likewise, freedom to decide learning paths might be of benefit field independent learners, however, would be counter-productive to those field dependent learners seeking structure from the learning materials.

In the next section hypermedia cognitive tools are discussed. The tools selected are purely arbitrary and used for the purpose of my starting to think about expanding the model of hypermedia learning presented by Chen and Macredie (2002) to include these tools. The purpose for expanding the model in this way is to build an instrument with which to analyse recorded episodes of learner interactions with hypermedia systems.

**Hypermedia -the cognitive tools**
The final part of this paper briefly analyses two hypermedia cognitive tools (information access and information searching). The discussion is confined to two tools as a means of maintaining this paper at an appropriate size and as an example of how the cognitive model of hypermedia learning might be expanded.

**Information access**
Some characteristics of information as hypermedia are that it is hierarchically organised (text, pictures, graphics, sound, video) “with associative or referential links able to be
manipulated using a graphical user interface (GUI)” (Lai & Waugh, 1995, p.26). It is a network of ideas/concepts connected on the basis of their associative or referential links in addition to organisational links and suitable for information searching and retrieval. Duchastel (1990) sees the important features of information in this form as being:

- non-linear access to information
- varied information access
- integrated information access
- ease of access to information
- free access to information

This implies that information seeking is the fundamental underlying hypermedia activity, one which Jonassen & Grabinger (1990) describe as “a fundamental learning activity, prrecurative to many others” (p. 13), and which Marchionini (1989) sees as a “special case of problem-solving” (p. 57). These activities would seem to be linked in most learning processes, i.e. learning is essentially a problem-solving activity in which information searching is an important skill.

The features of hypermedia information access identified by Duchastel (1990) would appear to accommodate different cognitive styles. For example, a field dependent learner searching information would be inclined towards an integrated information access which would provide linearity and structure, whereas a field independent information searcher would be more likely to do so in a non-linear way. Table 2 maps these features against cognitive styles.

<table>
<thead>
<tr>
<th>Hypermedia Cognitive Tool</th>
<th>Field Dependent</th>
<th>Field Independent</th>
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<tbody>
<tr>
<td>Features of Information Access</td>
<td>integrated information access</td>
<td>non-linear access to information</td>
</tr>
<tr>
<td></td>
<td>ease of access to information</td>
<td>free access to information</td>
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<td></td>
<td>varied information access</td>
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Table 2: Hypermedia Information Access tools mapped against Cognitive Style

Information searching
Research shows that: information searchers prefer facilities such as keyword search or an index mechanism (Joseph, Steinberg, & Jones, 1989). However, where search questions are vague, people tend to resort to browsing or exploring strategies (Marchionini & Shneiderman, 1988). Wright (1990) attempts to impose some structure on the search process by proposing that six different types of search tasks can be identified. These he describes as:

1. search target simple and fully known
2. search target simple but only partially known
3. search target complex and fully known
4. search target computed from on-line trade-offs and feedback from the computer
5. search target simple but unspecifiable to a computer, and
6. search target unrecognisable for the purposes of terminating the search.
Identifying search processes in this way seems to be educationally useful for two reasons. Firstly, these processes can be thought of as a range of pedagogical strategies capable of eliciting from learners a number of different learning outcomes. Secondly, this diversity of search processes would also require learners to engage in a range of cognitive activities and develop a range of cognitive structures.

Once again, it would seem possible to map these features against cognitive style. In terms of these information search processes, field dependent learners would be less likely to employ the search mechanisms of browsing and exploring or a search strategy where the target was unrecognisable for the purposes of terminating the search. Field dependent learners would be more likely to rely on the search being made clear by the learning system and not having to employ the search mechanisms of browsing or exploring. Table 3 maps these searching mechanisms and strategies against cognitive styles.

<table>
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<th>Cognitive Style</th>
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<tr>
<td>Information Searching</td>
<td>Field Dependent</td>
</tr>
<tr>
<td>Mechanisms</td>
<td>Field Independent</td>
</tr>
<tr>
<td></td>
<td><strong>Keyword Index</strong></td>
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<td></td>
<td><strong>Keyword Index</strong></td>
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<td></td>
<td><strong>Browsing</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Exploring</strong></td>
</tr>
<tr>
<td>Information Searching</td>
<td>1. search target simple and fully known</td>
</tr>
<tr>
<td>Strategy</td>
<td>2. search target simple but only partially known</td>
</tr>
<tr>
<td></td>
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Table 3: **Hypermedia Information searching tools mapped against Cognitive Style**

**Summary**

Research that has focussed on the interactions between the learner and hypermedia systems has identified that individual differences have significant effect on student learning. Among these differences, cognitive style plays an especially important role because they refer to learners’ information processing habits, representing their typical modes of learning. Therefore, building any kind of learning model for hypermedia must
take account of the learning needs of learners’ and their preferred mode of learning. In order to build a robust model of hypermedia learning the cognitive tools available in hypermedia systems need to be matched to these preferred modes of learning. This paper has attempted to take a small step in this direction by mapping the attributes of two such tools against a cognitive styles framework. With further mapping of this kind it is hoped to build a hypermedia learning cognitive framework which will allow for a richer examination of the cognitive impacts of hypermedia learning systems.

References


