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Navigation, Cognitive Style, and Seven-Year-Old Children's Use of CD-ROM-Based Hypermedia Resources

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Sixteen 7-year-old children from an urban primary school were assessed for cognitive processing style by means of the Cognitive Assessment System (CAS), which indicated their positions on each of the two dimensions of Attention and Planning. Then they searched for information on a CD-ROM of text and nontext-based hypermedia. Instruction and directions were given to the children and they were encouraged to search all the resources available on the hypermedia. Observation, and video recordings of the learning activities revealed that they had little difficulty in navigating the Frogs of Australia CD-ROM encyclopedia as an information resource. All the children searched for relevant information and analysed this information. Preliminary findings suggested that those children high on Attention as a subscale are more focussed during hypermedia based learning.

With the increased use of computers in schools there has been a growing interest in assessing and describing learning performance where students use software applications in various subject areas. There is additional pressure in schools today to consider the development of information skills as an essential outcome of their educational program. During learning, information seeking encompasses many comprehensive and higher order skills. The forms of skills that are appropriate in an information age are those given to inquiry of a problem solving and investigative nature (Riding & Grimley, 1999; Chambers, 1999). The introduction of new technologies into schools has seen an awakening of the awareness of information skills as an important outcome of schooling. These skills provide the user with the power to select the appropriate information and make relevant use of it.

Hypertext and Hypermedia-Based Learning

Research on young children's use of computers during learning, has mainly concentrated on text-based (hypertext) information sources (Shrivers, Rasmussen, & Bratton-Jeffery, 1997). Studies of novices in a hypertext environment revealed that nonskilled users in these environments view more screens than skilled users and do so in a nonsequential and inefficient manner. Levels of learning and understanding are thus significantly less among novices than trained users.

Despite its strong potential, hypermedia has problems in its use and application as an information source in education. Many potential uses of hypermedia and electronic books have been found to lack the cognitive skills, motivation, and attitude to learning required to take full advantage of the medium (Eveland & Dunwoody, 2001; Hill, 1997). Novices tend to browse when seeking information, which is an inefficient form of navigation when compared to indexing and using online guidance. Heller (1990) compared researching with hypermedia with discovery learning, and suggested that many younger students may not have the intellectual capacity to be able to actively ignore nonessential information as they browse a hypermedia system.

Research suggests that effective use of hypertext and hypermedia learning resources requires a sense of purpose. There needs to be a clearly defined objective or goal to be achieved at the end of the exercise (Land & Hannafin 1996). Ideally, the problem posed will focus learning within the environments that are relevant, assisting learners in navigating into areas of the hypermedia, which are consistent with the problem (Bowdish, Barab, & Lawless, 1994). Jonassen (1988), argued that users make navigational choices in a hypermedia based on the following criteria; (a) interest level of the reader; (b) curiosity fulfilment of the information; (c) personal relevance to the reader; (d) experience level of the reader; (e) information needs of the reader; and (f) task demands causing the reader to access the text.

Liu (1996) studied the use of multimedia resources by prekindergarten children. This study concluded that children as young as three years of age can readily use this technology. Recent research has also established that 11 and 12-year olds respectively (Chambers, 1999; Oliver & Perzylo, 1992) are able to extract relevant descriptive and qualitative information from interactive multimedia sources including video, graphical images, sound and textual resources. This was particularly evident when the appropriate information skills had been taught. These studies suggested that children use various search and problem solving skills, depending on the problem and individual metacognitive approaches to learning. The study concluded that the teacher's role as facilitator cannot be underestimated, and that appropriate teaching of search and metacognitive strategies is essential for improved learning.

There is also various literature available regarding the nature of navigation strategies by different adult users and how these can be matched to different topologies (Darken & Sibert, 1996). There are also various methods used to describe how adult users move around in information structures (Shneidermann, 1996). Navigation involves cognitive and perceptual processes including overall strategy decision (Westerink, Majoor, & Rama, 2000). Cognitive models of navigation based on what is known about the physical environment have been proposed (Watts, 1994; Edwards & Hardmann, 1989). Darken (1997) proposed a schematic model of the navigation process. It explicitly represents a task being performed, and includes strategy, movement, and progress evaluation. Also included is the implied existence of an internal model through the use of a priori spatial knowledge. The navigation framework by Spence (1999) has been used to explain the participants' navigational strategies in this study. This framework is made of the following four processes (a) a specific task being performed, (b) includes strategy formulation, (c) browsing, and (d) interpretation. Spence defines navigation as "the creation and interpretation of an internal model."

Traditional means of assessment of hypermedia use and navigation, relying mostly on measures taken upon completion of learning, fail to capture the dynamic unfolding of processes inherent to learning in general and navigational performance in particular (Rowe, Cooke, Hall, & Halgren, 1996). Other common processes of measure include stimulated recall (Hill & Hannafin, 1997), protocol analysis (Yelland, 1997) and logfiles (Barab, Fajen, Kulikowich & Young, 1996).

Currently, there is an increasing level of awareness of, and teaching in, information technology based inquiry as a process in primary schools. Those studies that have assessed primary school age children's use of both text and non-text based hypermedia resources have mainly concentrated on older children in upper and middle primary (Chambers, 1999; Hellar, 1990; Machionini, 1995; Frau, Midora, & Pedemonte, 1992; Oliver, 1992; Oliver & Perzylo, 1992). One of the main influences of search and information resource use strategies, is cognitive style (Riding & Grimley, 1999). Younger children are being encouraged to learn the use of information technology-based inquiry. Often these inquiries concentrate around a research topic that the children then explore.

Cognitive Styles and Learning

Cognitive processing style is an individual's preferred and habitual approach to organising and representing information (Naglieri & Das, 1997). An individual's cognitive processing style is their characteristic and consistent approach to organising and processing information (Pillay & Wilss, 1996). Cognitive style is thus defined as the characteristic cognitive, affective, and physiological behaviours that serve as relatively stable indicators of how learners perceive, interact with, and respond to, learning environments.

Cognitive processing style is a fairly stable and fixed chracteristic of the individual. Research by Fowler (1980) and Nagliere and Das (1997) argued that the various classifications of cognitive processing styles are actually different conceptualisations of the various dimensions. Cognitive styles influence the way individuals deal with and learn information, solve problems, make decisions and respond to other people in social situations.

The importance of theoretical models of cognitive processing styles has been emphasised by researchers who believe these may better define intelligence and cognitive functioning (Sternberg, 1990). A comprehensive analysis of the various labels, descriptors, classifications, and methods of assessment of cognitive styles, led to the development of the Planning, Attention, Simultaneous, and Successive (PASS) Cognitive Processing Model. This is a comprehensive theoretical model by which cognitive processing styles can be examined (Naglieri & Das, 1997). This model is derived from Luria's (1973, 1980) work on the neural basis of cognition.

PASS COGNITIVE PROCESSING MODEL

The PASS model proposed that three functional units are related to information processing, namely (a) cortical arousal and attention; (b) simultaneous and successive information processing; and (c) planning, self-monitoring, and structuring of cognitive processes. Because thorough summaries of the PASS theory and related research are presented elsewhere, (Naglieri & Das, 1994; Naglieri & Das, 1997; Naglieri, 1999), only a brief summary is provided here.

Planning processes provide for the programming, regulation, and verification of activity (Luria, 1973). The planning system provides motoric responses input and controls the decision-making functions of the brain. This system is positioned primarily in the prefrontal and frontal lobes of the brain and is the last to mature. This unit, organises the individual's conscious activity once information has been received, coded, and stored so the individual can form plans of action, inspect the performance, and regulate behaviour to conform to these plans, and then compare the effects of these actions with the original intentions so correction of mistakes is possible. Planning refers to the aptitude for asking new questions, solving problems, and self-monitoring, which Parrila, Aysto, and Das (1994) suggested may represent one of the most complex forms of human behaviour. Voluntary actions, impulse control such as visual search (Naglieri & Gottling, 1997), and linguistic functions such as spontaneous speech (Luria, 1980, p. 517) are under the responsibility of planning processes. The application of coding processes is an important function of planning that may be efficient and typical and thus result in good performances, or inefficient and unusual, thus resulting in poor results. The choice by an individual of one or another process depends on the demands of the task, the person's habitual mode of solving that type of problem, the person's competence in each type of process, and their knowledge base.

The Sensory Reception and Integration System is contained in the cerebral cortex and consists of the reception and analysis of input from the five senses and the integration of this information across sense hemispheres of the brain. The purpose of the second functional unit is the reception, analysis, and storage of information. This is done through simultaneous and successive processes. Simultaneous processing involves integrating stimuli into groups which are spatial (the ability to see a number of elements as a whole giving it a surveyable and almost Gestalt like quality). Simultaneous tasks require that the elements of the task be interrelated if the problem is to be solved correctly. Integration of the stimuli into a series where the elements form a specific chain-like progression involves successive information coding. In a successive processing task each element is related only to the next, there is no surveyability. Successive coding is required for skilled movements such as writing because this activity requires "a series of movements which follow each other in a strictly defined order" (Luria, 1966, 1973). Simultaneous and successive processing can be applied to various modalities, involving different stimuli and can occur at the levels of perceptual, memory, or conceptual tasks.

The Arousal system interconnects cells in the subcortical brain, the reticular activating system, and the frontal cortex. This unit is essential as a process, as it maintains a proper state of arousal or cortical tone. As such, the correct levels of arousal not only maintain cortical tone, but also provide the opportunity for other cortical activity. This includes "directive and selective attention" (Luria, 1973, p.273), and more complex forms of attention involving "selective recognition of a particular stimulus and inhibition of responses to irrelevant stimuli" (Luria, 1973, p. 271). Maintaining an appropriate level of arousal is also important for effective performance, because too much or too little interferes with proper processing of information and with making effective plans (Luria, 1973). Abnormalities in this system can lead to hyperactivity, hypoactivity, and/or sleep disorders.

Following Luria's detailed descriptions of the cognitive processing components, researchers such as Das, Kirby, and Jarman (1979) and more recently Naglieri & Das (1997) identified tasks intended to measure the viability of the cognitive processes of planning, attention, simultaneous, and successive (PASS model). The Cognitive Assessment System (CAS) (Naglieri & Das, 1997; Naglieri, 1999) is a cognitive assessment procedure based on this cognitive processing theory. While a number of studies exist that illustrate the implications that planning processes have for instruction (Cormier, Carlson, & Das, 1990; Dash, Das, & Carlson, 1992; Naglieri & Gottling, 1997), not many studies have been done to establish the implication of attention processes for instruction. Naglieri and Gottling (1994) have further shown that the planning and attention tests measure separate and distinguishable processes.

Cognitive Style and Learning with Hypermedia

The need for learners to reorient instructional material so it is congruent with their existing cognitive styles draws on the same pool of cognitive resources used for learning. When cognitive resources are directed at reorganising information, then reduced resources will be available for task performance (Pillay & Wilss, 1996). Information systems, in effect extend inquiry by way of schema-driven searches in a familiar domain rather than assist in the acquisition of enabling conceptual knowledge or skill. Lack of an adequate mental model may minimise the value of extensive domain knowledge during searches (Marchionini, 1995).

The design of instructional material in a manner suited to an individual's preferred cognitive style will reduce extraneous cognitive load and enhance learning (Wellar, Repman, Lan, & Rooze, 1995). This however, is not always possible within learning contexts. Within the area of hypermedia learning material, catering to all individual processing styles may not be easily achieved.

Based on the above discussion, this investigation was intended to add to the existing research analysing navigational performance and learning in 7-year old school children, in an open-ended learning environment such as hypermedia based CD-ROMs. The navigational framework by Spence (1999) has been used to explain the children's navigational behaviour. This study also investigated the influence of attention and planning as described by the PASS model on navigational behaviour, and used the CAS battery of standardized assessment tests to access these two dimensions.

Research Questions

The study hypothesised that if students are to make use of this hypermedia resource they needed to be able to make appropriate navigational choices. Furthermore it was hypothesised that given instruction on the process of gathering information, they would be able to use both text and non-text based sources of information to answer the search questions.

The following questions became the focus of the study:

- To what extent do young children obtain relevant information from both text and non-text based hypermedia resources during learning?
- Can young children make effective navigational choices in an open-ended hypermedia information resource?
- Do cognitive processing styles (attention and planning) influence the navigational choices children make when using hypermedia learning environments

Method

This research involved both standardised testing and naturalistic methods of data collection applied in a case study setting. The subjects were 16

(*N*=16) grade two students, in a government school in the Australian Capital Territory. Initially 22 were tested using CAS, but only 16 continued in the study due to attrition. All the students previously had exposure to computers at some stage in their school. All the students were familiar with the topic area of frogs in Australia, covered within the search process. During the previous term the students had looked at the topic of frogs in-depth, within their school class

MEASURES

The children were initially administered the DN-CAS Cognitive Assessment System (Naglieri & Das, 1997) test to measure their level of competence in their planning, attention, simultaneous and successive processes. All testing was conducted at the beginning of the study, but the results were not scored until the whole study was complete. Raw scores for each of the 12 subtests (3 for each of the PASS areas) were obtained and converted to standardised scores (Mean 100, SD 15) using test norms. Raw scores were converted into standardised scores by the normal procedure (Naglieri & Das, 1997). These scores were intended to provide a way to rank each child in comparison to those included in this study rather than in relation to a national norm. Only the scores on the subtests of attention and planning were used in this study, a general description of their component subtests are described later.

The subjects were then observed and video-recorded while using the Frogs of Australia hypermedia CD-ROM (Webster Publishing, 1995). The CD-ROM and how it was used is discussed below following the discussion of the CAS tests.

COGNITIVE ASSESSMENT SYSTEM TEST

Attention Tasks

Attention tasks require the individual to selectively attend to one and ignore other aspects of a two-dimensional stimulus. Individuals must focus cognitive activity, detect particular stimulus, and decide to respond to one and not the other competing dimension. The tasks always involve a competing stimulus that is salient or more salient than the target stimulus.

Number finding. The task consists of two pages of items on which subjects are required to identify, by underlining, specific numbers within rows of numbers that contain both targets and distracters. On the first page, the targets are the numbers 1, 2, and 3 when printed in bold-face type. On the second page, the targets are the numbers 1, 2, and 3 when printed in bold-face type and the numbers 4, 5, and 6 when printed in open-face type. Each page contains 180 numbers and 45 targets. The score for each subject will be obtained by summing the total number correctly underlined on each page.

Expressive attention. The task consists of three cards and is similar to the Stroop Task (Golden, 1978). The first card consists of rows of red, blue, green, and yellow, arranged in varying order. When presented with the first card, subjects will be required to read all the words in their order across the page as quickly as possible. The second card contains blocks of colors red, blue, green, and yellow arranged in rows in varying order. When presented with this second card, subjects will be required to name the colors on the card as quickly as possible in the order in which they are presented. The third card consists of the words red, blue, green, and yellow printed in color. However, the words are printed in a color that does not correspond to the written word. For example, yellow may be printed in blue and green may be printed in red. When presented with the card, the subject is required to name the color in which the word is printed. The time to complete this third card is used to score the task. These tasks have previously been demonstrated to measure attention (Warrick & Naglieri, 1993).

Receptive attention. The task contains four stimulus pages consisting of 13, 12, 15, and 12 rows of picture pairs respectively. Each item consists of rows of pictures which contain both targets (pairs that match) and distracters (pairs that do not match). The subjects' task is to find and underline picture pairs that match either on the basis of physical appearance (pages 1and 2) or pairs that have the same category name (pages 3 and 4). The time allocated is 120 seconds. The subjects must complete the subtest working from left to right and top to bottom. Individuals may not go back to check the page upon completion. The score of each subject is the ratio of the accuracy (total number correct minus the number of false detection) and the total time for each item. This task is based on the work of Posner and Boies (1971) and has been demonstrated as a measure of attention.

PLANNING TASKS

The planning tasks require an individual to develop some approach to solving the task in an efficient and effective manner. The task requirement is very simple and every item can be completed. Individual differences arise due to the requirement that some effective means of solving the problem be developed. Individuals have to create a plan of action, apply the plan, verify that the action taken conforms to the original goal, and modify the plan as needed.

Planned connections. The planned connection task consists of four items that are similar to the trail making test included in the Army Individual Test of General Ability (Reitan, 1955). The items require that subjects draw a line to connect a series of numbers in their proper sequence (eg., 1 to 2 to 3), where the numbers are arranged in a quasi-random fashion. The score is the sum of the time of completion for all the items. This task has consistently been demonstrated to load on a planning factor (Naglieri & Das, 1997).

Matching numbers. This is a four-page task, with each item composed of eight rows of numbers, with six numbers per row. Two of the six numbers in each row are the same. The length of the numbers differs on the various rows. Numbers increase in digit length from one digit on the first row of item 1 to seven digits on the eighth row on item 4. There are four rows for each digit length. Individuals are asked to underline two numbers in a row, which are the same. Each item is timed with 1 through 3 having 150-second time limit. Scoring for the matching number task begins with recording the time and the number correct (accuracy score) for each item. These are combined into ratio scores. The ratio scores are then summed across items to obtain the subtest raw score which is then converted to the subtest scaled score. This task has been demonstrated to load on a planning factor (Parrila, Das, & Dash, 1996).

Planned codes. This task consists of two items in which the participant is presented with a page containing two boxes. The top of the boxes contains the letters A, B, C, and D. The bottom part of the box is divided into half and remains empty. The participants are instructed to fill in the bottom portion of the box with a sequence of Xs and Os that correspond to that particular letter. For example, the subject may write XX under the letter A, OX under B, and so forth. On the first task, the empty boxes are arranged in a vertical fashion so that the first columns consist of all As, the second Bs, and so forth. In the second item, the empty boxes are arranged in a diagonal rather than a vertical column on the page. Recognition of the pattern in which the letters are arranged should facilitate completion time. The correct sequence of Xs and Os for the particular item is located at the top of the item page so that the subject may refer to it as needed.

A time limit of 60 seconds is imposed for each stimulus page and the score is the total number of correct responses. Scoring begins with recording time and number correct for each item. These are combined into ratio scores, which are then summed across items to obtain a subtest raw score. The raw score is converted into the subtest scaled score. This task was previously demonstrated to load on a planning factor (Naglieri & Das, 1997).

FROGS OF AUSTRALIA CD-ROM

The CD-ROM used in this study is *Frogs of Australia* (Webster Publishing, 1995). This CD-ROM is an interactive multimedia program. It is published as an electronic encyclopedia on the various Australian frogs. It has been designed with an instructional interface that gives full user/learner control. All the documentation for the program is CD based with a help and instruction sequences readily available. The program contains colour video clips, graphical photos, textual information, and sound capabilities. In all there are 203 frogs and other animals that form part of the CD-ROM.

The starting screen provides access through a menu system to a help routine, tutorial, and information regarding frog topics. The menu choice leads on to other more specific choices. If students elect to find out information about a specific frog, they can type in a word and this information is provided. This information such as a type of frog comes up with a graphical photo and textual information. There is an icon for a video clip about the frog. Further screen icons, give information on distribution, habitat (includes, climate, vegetation, rainfall, geographical region, and terrain) and population status.

There is a tool bar with various capabilities including drawing tools, printing options, note taking, clipboard, back, forward, and end-page, icons. These make the CD-ROM very interactive. Within this option are others that provide access to user tools/options. The tool bar provides an easy access to other levels and choices from any screen.

HYPERMEDIA EXERCISE

The students were introduced to the CD-ROM, *Frogs of Australia* (Webster Publishing, 1995). Through a 10-minute discussion and hands on exercises, the students working in pairs (dyads) were introduced to the various capabilities of the CD-ROM. The navigational aids such as the use of the tool bar was also explained.

The information to be retrieved was also discussed by the researcher, and a work sheet outlining specific questions was given to each dyad. The researcher discussed these with the students to make sure they understood what was required of them. The children were also asked to speak loudly, as they worked on the task, so their spontaneous speech could be recorded for later analysis. The children were free to seek help from the researcher as necessary. An interview was conducted with the pairs immediately after the exercise to determine the children's knowledge of the information source and their understanding of the material researched

The navigational choices 7-year-old children make while accessing information from both text and nontext hypermedia-based information resources were assessed. The extent to which these navigational choices influenced effective learning outcomes was also assessed. While the children were asked to answer specific questions, their thought processes were verbalised during the paired exercises. The study gathered both factual data, and descriptive data made up of their thoughts, judgements, and perceptions during the exercise. Their verbal communication during the exercise also gave insight into their cognitive and self-regulatory thoughts in making the various navigational choices.

HYPERMEDIA-BASED DATA COLLECTION

One multimedia computer, with CD-ROM capabilities, was used for the study. During one 40-minute session, the students, working in pairs, accessed information as requested on their work sheets. The hypermedia information source was not restricted, and could be video, audio, text, or graphical photos. The researcher observed the activities of the students through a one way observation window, while video-recording their activities.

In this study, the locations of "point and click" responses that activated hyperlinks or buttons were recorded as navigational points (Schin, Schallert, & Savenye, 1994; Hill & Hannafin, 1997). As each pair worked on the tasks outlined in the study, all the commands that they made and the resultant moves were recorded on videotape. The activities that were recorded include navigational actions, information accessed, and verbal communication between the working pairs. These provided a reliable record of actions and system responses associated with the search. Simultaneously, a camera recorded the interactions of the children as they engaged in the problem solving activity, and the computer screen showing all navigational choices made. The two video inputs were then mixed using a digital mixer so that both the computer screens containing the strategies and the children interactions could be viewed simultaneously and analysed cohesively (Ogonda, 2000).

DESIGN AND ANALYSIS

The study focussed on the strategies and interactions of the pairs of children. The methods combined both descriptive and analytical approaches. The research was descriptive in that the goal was to describe evidence gathered including the perspective of the participants and the researchers. During analysis, the information was transformed through induction. In order to identify themes and trends, definitions and exploration, codes were used to categorise the data collected. Initial codes were then refined and expanded as needed during the analysis of the study (Yin, 1994).

Analysis of the videotapes and interviews was done to establish the navigational choices, information accessed by the children and the verbal communication between the working pairs. This analysis was done to determine patterns of behaviour and establish coding criteria of the navigational behaviours of 7-year-old primary school children. Records of users' navigational choices through the information space can be used to infer user's changing intentions as they interact within the computer space. These responses included time, traditional right and wrong responses, and specific aspects of the information users chose to examine (Hill, 1997).

Results and Discussion

Given the nature of the qualitative analysis, as well as the amount of data processed, results and interpretations are discussed together. The discussion focuses on the 16 subjects for whom the detailed analysis was conducted, and is not intended to be generalised beyond the scope of this study.

An analysis of the statements used by the children to guide the research process showed the need for qualitative and descriptive data in the research process. The focus questions mainly sought to examine various frogs by specifying characteristics of each. The choice of which frogs to discuss and describe was not restricted, with the questions structured such that the students had to make choices between several frogs. The interviews and their verbal interactions, showed that the children answered the questions, based on the information provided on the CD-ROM. In all examples given, verbal interactions are shown in plain type, computer commands are shown in italics, and researcher observation are shown in angled brackets (<>). The terms DI, D2 refer to the two children that form a dyad.

COGNITIVE STYLE AND INFORMATION SEEKING BEHAVIOUR

The children were tested on their cognitive styles using the DN-CAS Cognitive Assessment System (Das & Naglieri, 1994). The children were tested on the attention and planning subscales. A number of pencil and paper tests were administered to the children to establish their particular styles. Each child's three subtest scores in the CAS test were used to obtain a PASS scale score. These scores were used to sort the values into two main groups on the basis of attention and planning (high attention-high planning and high planning- low attention). The following mean scores were obtained for the groups respectively 125-110 and 120-94.

The researcher hypothesised that the cognitive processing style would influence the ways in which the children approached the information seeking exercise. Riding and Grimley (1999) investigated the influence of cognitive style (wholistic-analytic dimensions) on the use of multi-media and traditional text-based work, by 11-year-old children. Their study compared children's overall science performance in traditional and multimedia contexts. The study determined that children of a specific cognitive style interact with information of represented in specific ways, whether multimedia or text-based. And this in turn influences learning (Riding & Grimely, 1999).

In this study the influence of attention was specifically interesting. Planning was not seen as influencing the manner in which the children used the information resource. Children low on the attention sub-scales were inclined to not keep on task. They diverted from the questions asked, did not commit to completing the required information tasks and tended to be "impatient" with the hypermedia environment. In a hypermedia environment, there is varied information provided in text, video, still images, and audio. The competing information sources may prove confusing for some users, resulting in each being accessed but without depth and/or purpose. One other possibility is that younger children simply did not understand the task and did not translate the task demands appropriately (Guttentag, 1989). In the current study, the children did not appear to have difficulty in understanding the task demands.

The small nature of the study needs to be taken into consideration. A larger study with more subjects is currently underway and may help answer more effectively some of the relationships touched on above.

PROBLEM SOLVING AND PRIOR KNOWLEDGE

The format used in the children's earlier classroom discussions and prior knowledge of frogs guided their search for information on the CD-ROM to answer the various focus questions, for example on the question " Put the following pictures items in their correct order." The children first had to work out that the pictures depicted the life cycle of frogs, then arrange the pictures in their correct order. There were five stages in the life cycle depicted.

Independent of medium, learners with extensive domain knowledge consistently out-perform their counterparts with limited prior knowledge. High domain knowledge enables learners to better anticipate, as well as to identify relevant terminology than does limited domain knowledge. This enables learners to generate powerful strategies that are largely independent of specific information systems (Schin et al., 1994). This in effect helps extend inquiry through schema driven searches in a similar domain, rather than assist in the acquisition of enabling conceptual knowledge and skills (Marchionini, 1995). In their study, Hill and Hannafin (1997) found that participants with prior subject knowledge were not only able to integrate and retain new information, but were also able to use a variety of search terms as they searched for information in a hypermedia system.

In this study, the children's natural curiosity may suggest that the researcher-identified questions may need to balance with issues within topics that are of genuine interest to the children. The researcher provided the focus questions as it was felt the participants might be too young to adequately form their own. Future work may need to include information skills, which let the students with their teachers narrow topic areas on their own into key words to guide their queries. This has been researched with older primary school children and adult participants (Perzylo & Oliver, 1992; Chambers, 1999). The fact that most of their search strategies were guided by their prior experience of and understanding of the topic, suggests that, with the right guidance, 7-year-old children are capable of identifying and using relevant, specific words and search strategies during hypermedia based, information searches. For example,

<*D1points to "contents," D2 obliges and clicks contents icon*>

D1: We should look at another one I already know something about frogs

D2: What? <continues reading information on the screen. *They move from page to page* reading information on distribution of frogs. *D1 clicks on Cane toads*, D2 tries to get mouse, unable, takes question sheet with life cycle of frogs picture. Looks at it for a few minutes. *D1 joins in, points mouse to contents icon, scrolls over drop down menu.* >

D2: Which one did you go into?

D1: That one—lets go into that one—<*chooses "breeding frogs"*>

USE OF TEXT AND NONTEXT-BASED SOURCES OF INFORMATION

The drawing tool, proved an interesting feature for the children, yet distracted them from the objective of the exercise, as they tended to spend a lot of time on it. They almost always looked at the graphical picture and video clip provided of the frog species discussed. They would then discuss the colour, shape, size, and position of the frog as seen on the screen. The graphical picture would be changed into drawing mode, and the children would then try and trace the physical features of the frog. Interestingly not all of the children chose to read the associated text, and concentrated more on the audio/video accompanying the text. This is in contrast with studies by Chambers (1999) and Oliver and Perzylo (1992) in which all subjects chose to use text-based information and did not access the pictorial or audio facilities available. This can be explained as "sound information handling skills" in older subjects (Chambers, 1999). It may also be explained as subjects' decision to look at one source of information due to perceived ease of use (Cohen, 1973). Salomon (1983) found that young students' perceptions of mental effort associated with learning activity often influenced the learning that was achieved.

In this study, where only text was provided, subjects would read as little of this as possible. Some of the children failed to complete reading the provided text, yet almost always listened to the whole of the sound section or viewed all of the video clip provided. This could be an indication of their reading abilities and interest rather than just interest in a mode of information presentation. Though most were confident in their search, all needed to return to the focus questions several times to ensure they were on task. There was a genuine curiosity to find out a lot more than that requested, but the focus questions helped the students keep track of their objectives. To the question “Choose one frog of your choice, how does the weather affect where it lives?”

D1: Where do we go now? <while scrolling through menu items, chooses “brown Frogs – let us see where they live *chooses correct icon,* Where they get their rain. *Back into overlay map.* Oh! There is trees all around there. *Clicks on vegetation icon and then moves back to brown frog picture and text.*

D2: So what have we figured out so far? <D1 doesn’t answer> *Clicks on Cane Toads. Both watch video, attentively listening to audio*.

D1: We don’t have to learn about cane toads. *D1 goes back into overlay map for distribution of brown frogs, and rainfall patterns.*

D2: We have to find some facts,

D1: Which one has some fact in it? *Scrolls through contents menu clicks on brown frog breeding cycle.*

DEEP AND SURFACE LEVEL PROCESSING

During their verbal discussions, the children made comments about why they chose specific information to view or include in their discussions. The navigational choices also indicated a need to provide queries that allowed for more focussed and in-depth exploratory behaviour. This would ensure that there was wider and deeper access into the CD-ROM, such that the information was not accessed linearly, as in a book, but thematically as an information resource which could be approached from any direction.

The children needed to balance whether just knowing the answer or seeking an understanding of the question was necessary, such that they answered it in a way that did not just reproduce information but involved an active search for meaning. Some of the children displayed a need for understanding, and responded by searching for more than just surface information. Chambers (1999) in his study, found that depth of processing was displayed by 11-year-olds through the ways they developed search strategies to access information in the hypermedia. The participants needed to interpret search questions in a manner that not only promoted the reproduction of information, but also provided an active search for meaning.

In an example to the question “write 3 sentences each about the following (a) frogs eggs (b) tadpoles (c) frog’s habitat?” the following conversation and activities were recorded.

D1: Don’t do that one *pointing to ticked menu item, which indicates items already accessed.* <D2 looks at the question and then back at the screen>

D2: No, but we are supposed to learn about frog’s eggs <D1 takes the question and looks at it. Reads it loud> We saw it! <referring to frog’s eggs> *Clicks back into breeding cycle. Points to video section and plays video.*

D2: They have got gel around them. <video ends>

D1: But we haven’t really learnt about it, you know, when we showed it just then. <Looks again at question and takes the mouse> *Plays video again, Then clicks on to associated text, moving from page to page.*

Navigational Behaviour

The analysis of the navigational behaviour is based on the framework of Spence (1999), who defines navigation as the creation and interpretation of a mental model. This study describes children’s navigational behaviour and how this may or may not differ from task-oriented adult navigational behaviour. The students in this study were all familiar with computers. They had all been exposed to computer use at school, and understood what a CD-ROM was. They also knew what “looking for information to answer questions” meant. As such, the students were aware of information seeking from various resources. They had not used CD-ROM specifically for information seeking, but had used various CD-ROM hypermedia-based instructional materials. Analysis of the data indicated that the navigational behaviour of the children could be divided into categories. These categories have been established based on the navigational choices made and the depth of processing of information observed in the children. Their searches also provided information on the relevance and depth of the children’s searches. An example for each criteria follows.

Browsers. These students asked repeatedly as to the purpose of the exercise even after this had been explained. They tended to:—Quit the task without completing all of the questions; move from screen to screen without really finding out more about what information was included; move from screen to screen without an idea of which specific questions they were answering; did not complete the worksheet within the allocated time and asked for help from the researcher, more than all the other groups.

The browser activity is very similar to what Spence (1999) described as browsing and Carmel, Crawford, & Chen (1992) discussed as "Scan-browse: scanning for interesting information." The browsing activity did not proceed beyond basic "registration of content" (Spence, 1999), and no apparent browsing strategy was formulated.

Exploring behaviours. These students made full use of the hypermedia resource; looked at various screens, including unrelated yet interesting topics such as *classification of animals*; they were able to discuss the information gathered as they moved along; they accessed the drawing tools more; used the deeper level icons on the screen more (distribution, overlay for climate of Australia, etc); they asked for help occasionally, and yet were satisfied to find out for themselves the various capabilities of the CD-ROM, for example, discussed among themselves what a menu item was for, and then discovered this through trial.

Though similar to browsers in that they did not consciously pursue the goal of the task, explorers differed in their apparent use of "weights" (Spence, 1999). That is, users selected the nature of content to be registered based on anticipated use or value. The children seemed to select content to be viewed, interestingly enough, to maintain motivation based on their own perception of the hypermedia. As browsing proceeded, the user's initially developing internal models further guided their searches into areas of interest.

Fact-finding. These students answered all questions required; asked for "help," yet if the researcher waited a while before giving help, continued on, and found ways of solving the problem; answering questions on the worksheet was the end goal, to cover topics as precisely as possible; they did not spend time "discovering" the hypermedia resource, and these children were very focussed as to the purpose of the exercise.

The tasks in the information search guided user navigation, influencing both their navigation behaviour and the formation of mental models (Westerink et al., 2000). As browsing proceeded, newly observed data may have been integrated with existing internal models made up of relevant prior domain and system knowledge. This process is called "modelling" by Spence

(1999), and "review-browse" by Carmel et al. (1992). The manner in which the children resolved their own problems suggested that modelling and browsing proceeded concurrently (Spence, 1999).

Exploration and fact finding. These students answered all the questions required; did not exhibit "help" behaviour; found innovative and different ways of using the CD-ROM facilities; exhibited a lot of "discovery" behaviour which acted as a motivator to the children to search various other areas of the information resource; readily discussed their prior knowledge of frogs and other frog-related topics not directly requested in the worksheets; spent a certain amount of time doing things other than finding out the frog related facts, yet they completed their worksheet within the time allocated.

While the users were guided in their information searches by the task demands, they did not restrict their navigational choices to solving the task demands. They effectively used the hypermedia for solving tasks required, while also effectively using and viewing other information provided. The processes of browsing and modelling appear to be relatively easy to the participants. This may indicate that they were relatively comfortable with the "externalization" of the CD-ROM content material, and how this was transformed to enhance the formation of internal models (Spence, 1999). The process of externalisation makes modelling easier at three levels (a) the inherent structure of the data is changed into an externalised structure, which in turn influences the user's cognitive map, (b) the changed data not only involves the selection, encoding, and presentation of raw data, but the manner in which these three processes can be influenced through interaction, and (c) it is the imposed structure that is browsed to create an internal model which then supports navigation.

Conclusions

The work of Oliver and Perzylo (1992) has demonstrated that 12-year-old children can extract relevant material from hypermedia-based resources. The present study has shown that, though there were varying information seeking behaviours, 7-year-old students have the capacity to gather information from CD-ROM-based hypermedia resources. Hellar (1990), discussed the difficulties students face when learning with open-ended hypermedia resources, and suggested that younger students may lack the intellectual capacity to be able to actively ignore nonessential information as they browse the hypermedia system. The results of the present pilot study, suggest that with appropriate instruction and guidance, children as young as seven years old, are capable of obtaining relevant information from open-ended hypermedia-based information resources. Future studies will attempt to establish the underlying cognitive reasons for the variety in navigational and information seeking behaviours.

This study also pointed to the importance of using established prior knowledge to develop or further extend search questions and strategies. During the learning activity the children made reference to the fact that they had learned a particular aspect of frogs in their classroom. Thus prior knowledge guided them as to the depth at which they needed the present information.

The study results were able to define four different categories based on navigational behaviours. The four categories are “browsing,” “fact-finding,” “exploring,” and “exploring and fact-finding.” These categories appear to fit in with Spence’s (1999) framework for navigation, and appear to suggest that navigation occurs in a continuum. The study also suggests that the effectiveness of one’s navigation depends on the application of the relevant appropriate mental and perceptual strategies. These are preliminary findings, based on a small qualitative study. The findings can thus only be generalised to the population involved in this study. Future work needs to establish through research, the applicability of the navigation framework presented by Spence (1999) in both physical and virtual domains.

The variety in information seeking was seen to affect the navigational choices made and thus the level at which the students gathered information. Many of the students, especially those within the “exploring” and “fact-finding and exploring” categories showed a lot of curiosity in discovering information. These students wanted to know more than that required of them on the work-sheets, pointing to a need to balance interest of students and focus questions for information searches, even with students this young. All this may suggest that the information seeking behaviour of students will determine the level of inquiry, navigational choices that they make, and ultimately the amount of learning that occurs within CD-ROM hypermedia-based resources.

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