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A ‘Rich Picture Approach’ to Researching Cognitive Activity during Hypermedia Learning

Fred Beven, Griffith University, Queensland, AUSTRALIA

Abstract: The aim of this research was to develop and evaluate the effectiveness of a ‘rich picture’ approach to eliciting the metacognitive processes of learners engaging with hypermedia when undertaking a vocational course. The ‘rich picture’ approach to knowledge elicitation employed a combination of ‘activity’ and ‘verbal data’ analysis (Stahl 2004), and is a hybrid of both think-aloud and stimulated recall methods. That is, the method captured real time data about what the learner was doing and what materials were being engaged with, and stimulated recall on why they were doing it. Sessions were transcribed and the cognitive processes were coded and analysed using a taxonomy derived from Brown et al (1983), Pintrich (1989), and Meijer et al (2006). The ‘rich picture’ methodology was found to be effective in capturing multiple instances of cognitive and metacognitive activity. The data were rich in processes related to learner interaction with the hypermedia, however, it was not always possible to clearly determine whether some processes were merely cognitive or if they involved metacognitive control or monitoring. Hence, it is concluded that any further refinement to this rich picture approach needs to focus on improving the guidance of subjects to a more comprehensive interpretation of their interactions with the hypermedia. It is argued that this ‘rich picture’ methodology and its continued refinement have important benefits in illuminating the cognitive and metacognitive processes that are critically important to hypermedia design and to extending the theoretical understanding of learning with this medium.

Keywords: Metacognition, Learning, Cognitive Processes

Introduction

The FIRST PART of this paper examines metacognition as a cognitive activity. Next a metacognitive activity framework developed from recent work undertaken by Meijer, Veenman & Hout-Wolters (2005, 2006) is discussed. A methodology developed to capture metacognitive data using computer software is then outlined. Finally, some preliminary analysis of data collected from students interacting with educational hypermedia is presented.

Research on knowledge elicitation (e.g. see (Nisbett and Wilson 1977; Ericsson and Simons 1993; Chipman, Schrangen et al. 2000; Cooke 2000) has highlighted the importance of combining approaches to knowledge elicitation, which capture knowledge in different ways, e.g. protocol analysis, process tracing, interviews and stimulated recall, each with its own strengths and limitations and claims to validity. The research is significant, firstly, in its contribution to a better understanding of learners’ cognitive and metacognitive processes, as they engage with instruction mediated by hypermedia. Because of the structural features of nodes and links and the non-linearity of hypermedia it is likely that different kinds of demands are imposed upon the learner. That is, demands that are different from those used in engaging with written text, or traditional classroom activities. Consequently illumination of the cognitive and metacognitive processes is critical to both improving hypermedia design and to extending the theoretical understanding of learning with this medium.

Metacognition

Metacognition has been identified as that body of knowledge and understanding that reflects on cognition itself, or the mental activity for which other mental states or processes become the object of reflection (Yussen 1985). Metacognition is often referred to as ‘thinking about thinking’ or thoughts about cognition and has been a topic of scholarly interest since the 1970’s. Flavell is most often cited as the originator of the term metacognition. He defined metacognition as “one’s knowledge concerning one’s own cognitive processes and products or anything related to them, e.g., the learning-relevant properties of information or data.” (1976, p. 232).

Metacognition as the Control and Regulation of Cognition

Flavell (1976; 1992) considered metacognitive knowledge to be the declarative knowledge one has about the interplay between personal characteristics, task characteristics and the available strategies in a learning situation. For example, in returning to an on-screen learning unit the learner might realise that what is presented is material that they have already...
mastered and they move on quickly. In this instance they have used the knowledge that when encountering material that is already known, it is most efficient to quickly move through that material. Flavell identified four broad classes of knowledge that a learner might acquire about some cognitive activity: tasks, self-knowledge, strategies, and interactions. A definition and an example of each follow.

Tasks – refer to the knowledge about how the nature of the task influences performance on it. For example, knowing that it is easier to recognise an on-screen icon than it is to recall a labelled name.

Self-knowledge – about one’s own skills, strengths, and weaknesses as a cognitive being. For example, knowing that using pull down menu structures is easier than recalling the keystrokes associated with shortcut keys.

Strategies – knowledge about the value of alternative strategies for enhancing performance. For example, knowing that when multiplying a number by nine, it is easier to multiply by ten and subtract the multiplier.

Interactions – knowledge about the ways in which the abovementioned categories of knowledge might interact with one another to influence the outcome of some cognitive performance. For example, knowing that it is of help to repeat a list of items in order to remember them (task), as opposed to repeating an instruction that is not understood the first time (strategy).

These interactions have been articulated by a number of authors. Originally, Brown (1981) identified a set of metacognitive strategies that were considered to be of a general nature and thought.

Brown (1981) argued that there are two kinds of metacognitive knowledge – static and strategic. She regarded static knowledge as the verbalisable things people state about cognition. Strategic knowledge, by comparison, is the steps individuals take to regulate and modify the progress of a cognitive activity as it is occurring. While acknowledging that there might be a host of specific strategies to regulate particular cognitive activities, she does suggest a list of general strategies that are present in almost all forms of cognitive activity. Later, Brown, Bransford, Ferrera, & Campion (1983) considered these general metacognitive strategies to be:

- **Planning** - (figuring out how to proceed). Activities that assist the learner to plan the use of strategies and the processing of information. These assist the learner to activate relevant aspects of prior knowledge that may make the organising and comprehending of the material easier,
- **Monitoring** - (taking stock of how well one has progressed towards a goal in the cognitive activity). These activities are seen as an essential aspect of the material with which learners are engaged, and integrating it with prior knowledge, and
- **Self-regulation** - (checking and correcting as they proceed on a task). These activities are assumed to assist the learner to improve their performance and are related to monitoring activities.

Yussen (1985) believes that these are the major ideas that have structured the definition of metacognition as a field. However, other authors have added additional insights to this list. For example, Pintrich (1989) showed that there was a pattern of relationships among the various cognitive, metacognitive and motivational components of student learning. He argued that each of the components does not operate in isolation and that the motivational aspects of a task might be just as important also.

Recently, Meijer, Veenman, & Van Hout Wolters (2005; 2006) reported a taxonomy of metacognitive activities developed for a study in which they were attempting to establish relationships between intelligence, metacognition and learning in different knowledge domains. Working from thinking-aloud protocols from learners in the fields of history and physics they developed a taxonomy (see Table 1 below) that built upon the earlier work of Brown and others.

The authors made no claim about the generalisability of their additional categories, although they do, at least on the surface, seem applicable to domains other than history and physics. In their study, the history learners were engaged in a text-studying activity, whilst the physics learners were engaged in a problem-solving activity. In hypermedia learning settings interacting with text is a major activity. Moreover, given the independence and autonomy afforded the learner in such settings, it could be expected that they would need to engage in a range of problem-solving activities in order to successfully advance their learning. Therefore, it is argued that engaging with text and problem-solving are major learner activities in hypermedia learning settings. As a consequence, this taxonomy ought to be suitable for studying such settings.
Table 1: Taxonomy of Metacognitive Activities: (with Examples)

<table>
<thead>
<tr>
<th>Main Category</th>
<th>General</th>
<th>History</th>
<th>Physics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orientating</td>
<td>Activating prior knowledge</td>
<td>n/a</td>
<td>Observing (tables, diagrams)</td>
</tr>
<tr>
<td>Planning</td>
<td>Sub goaling</td>
<td>Reading notes</td>
<td>Set up coordinate system</td>
</tr>
<tr>
<td>Executing</td>
<td>Note taking</td>
<td>Offering explanations</td>
<td>Converting units</td>
</tr>
<tr>
<td>Monitoring</td>
<td>Noting inconsistencies</td>
<td>Deliberately pausing</td>
<td>Give meaning to symbols</td>
</tr>
<tr>
<td>Evaluating</td>
<td>Checking</td>
<td>Reading goal accom-</td>
<td>Verifying</td>
</tr>
<tr>
<td>Elaborating</td>
<td>Paraphrasing</td>
<td>plished</td>
<td></td>
</tr>
</tbody>
</table>

Table 1: Taxonomy of Metacognitive Activities: (with Examples)

Next, a study in which computer software was used to capture learners’ cognitive engagement with educational hypermedia is briefly outlined. The methodology used and a preliminary mapping of some data against the metacognitive taxonomy are then provided. Finally, its effectiveness is discussed.

The Study

Method

The study followed a qualitative paradigm and focussed on gathering data from students undertaking a web-based course in computer networking as they interacted with the web-based courseware. The data were collected using screen based video capture software (Camtasia) that recorded the learner’s interactions with the software as a real time video in an AVI format. Immediately following the initial capture the session was replayed to the learner during which time they were continually asked to provide explanations of what they were doing, and what was their thinking behind this doing, or why they were doing it. This follow-up event was recorded using the capture software, and differed from the original recording only through the addition of the learner’s recall of their cognitive and metacognitive actions. That is, ‘a rich picture’, of the event was captured for later analysis. It is a ‘richer picture’ because the learner was able to ‘relive’ the event and provide a much richer and more detailed account of the thinking and actions that underpinned the learning. The same level of detail could not be expected through the more traditional approach to stimulated recall. Moreover, the ‘reliving’ as opposed to the ‘recalling’ of the learning that took place ought to ensure more fidelity in the data.

The steps of the study were as follows:

1. Data Collection
2. Capture Software sent to students for loading onto their computer
3. Data collection undertaken with each individual student and transferred to CD
4. Data analysis
5. Data transcribed to framework for initial review (see Figure 3)
6. Data specific taxonomy compiled from initial framework (see Tables 2, 3 and 4)

Cohort

The participants were 4 students who self selected by volunteering from a class group of 12. This class group was chosen for a number of reasons. Firstly, the learners were engaged in on-line learning. Secondly, as most of the web-based interactions happened on home computers, it was critical that the computer on which they were working had the disk capacity to hold video files and had a read and write CD ROM for transferring back these large files. Thirdly, the student cohort was known to possess the technical skills to load the capture software, activate the capture, and transfer the results to a CD-ROM. All of the volunteers had computers of sufficient capacity and also had the necessary technical skills.

The Hypermedia

The courseware consisted of a series of topics constructed as a set of documents or screens. Each respondent was asked to work through a topic they had not previously attempted. The courseware allowed them to choose the manner in which they did this. For example, it was possible for them to move through the screens in a linear fashion following the structure of the courseware. Conversely, using a number of navigational aids that were part of the software, the learner was able to select alternate learning pathways and move between screens in a manner of their choosing. A sample screen is shown below as Figure 1.
contained text, whilst the left hand side provided a graphics display area. Not all screens contained graphics and in those cases where they did not the graphics area contained a watermarked logo to signify this. Some screens contained multiple graphics, indicated by numbered buttons on the left side of the graphics segment (see Figure 1 as an example). The additional graphics could be viewed by placing the mouse cursor over the appropriate number. On many screens the amount of text was greater than that able to fit in the text window. In these cases scroll bars were provided. Also, a series of navigational aids were provided across the bottom of the screen. These allowed the learner to move forward or backward in a linear fashion or to move directly to some other part of the courseware. The navigation bar also provided access to a set of review questions, a quiz and a glossary. As a result, the learner was able to follow the pathway offered by the courseware, select an alternate learning pathway, or test their knowledge to help them determine their next course of action.

Data Analysis

In order to assist in the later analysis of the data the learners were asked to place the cursor in the area of the screen they were currently using. For example, if they were reading text they moved the cursor down the text as they read. Further, the researcher sat in the background both observing and recording the actions of the learner. These notes were used to prime the stimulated recall captured as the data set.

It was the ‘rich picture’ recorded version of the learner’s interactions and navigational decisions that formed the data set for initial analysis. A framework for this initial review of the data was developed. Each of the video files was viewed and the data mapped onto a four-column table (see Figure 2 below).

The first data column contained a graphic of the screens selected by the learners in the order in which they worked through them. The second column indicated whether or not the user engaged with that screen or simply by-passed it. The third column captures those utterances made by the learner during the stimulated recall recording that were considered to be describing their cognitive and/or metacognitive actions. The final column was a record of the user transactions identified on the recording as well as those transactions noted by the researcher whilst observing the learning session. Together these provided a comprehensive picture of the navigational/learning track chosen by the learner and insights of the cognition driving these actions.

Figure 1: Typical Screen Layout and Navigational Devices
Figure 2: Sample Data Used for the Preliminary Analysis

The final step was to map the user transactions onto the metacognitive taxonomy. The preliminary results from this mapping are outlined below.

**Findings**

The tables below provide some examples from the data analysis. They do show that it has been possible to capture and identify the metacognitive activity from a hypermedia learning setting. While this is significant and has extended our capacity to reach into a learner’s cognitive activity while learning with hypermedia, there are some cautions. It remains somewhat problematic as to whether some transactions captured here were in fact metacognitive rather than cognitive. That is, it is possible that in some instances an action could only be accurately identified as either cognitive or metacognitive by knowing more about the particular context of its use.
### Table 2: Examples of Planning and Monitoring from the Data

<table>
<thead>
<tr>
<th>Metacognitive Learning Strategy/Skill</th>
<th>General Skill</th>
<th>Subordinate Categories</th>
<th>Activities within the Data</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Planning</strong> (Brown et al, 1983)</td>
<td>Setting Goals</td>
<td>Skimming a text before reading</td>
<td>Removing extraneous parts of the screen</td>
</tr>
<tr>
<td>Help learner to plan the use of strategies and the processing of information</td>
<td></td>
<td>Generating questions before reading</td>
<td>Setting up Notepad software</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Undertaking a task analysis of the problem (Pintrich and Schrauben 1992)</td>
<td>Undertaking software Quiz</td>
</tr>
<tr>
<td><strong>Monitoring</strong> (of one’s thinking) (Brown et al, 1983)</td>
<td>Checking comprehension (Pintrich, 1989)</td>
<td>Tracking of attention while reading a text or listening to a lecture</td>
<td>Use Software Glossary</td>
</tr>
<tr>
<td>Activities are seen as essential elements of MC.</td>
<td>Noting inconsistencies (Meijer, Veenman et al. 2005)</td>
<td>Self-testing using questions about the text material (to check understanding)</td>
<td>Re-reading text</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Monitoring speed and adjusting to time available (Pintrich &amp; Schrauben, 1992)</td>
<td>Refer to software Index</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Deliberately pausing (Meijer et al, 2005)</td>
<td>Undertake lab activity</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Undertaking Quiz to check progress</td>
</tr>
</tbody>
</table>

### Table 3: Examples of Self Regulation from the Data

<table>
<thead>
<tr>
<th>Metacognitive Learning Strategy/Skill</th>
<th>General Skill</th>
<th>Subordinate Categories</th>
<th>Activities within the data</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Regulating</strong> (Pintrich 1989) Self regulation (Brown, Bransford et al. 1983)</td>
<td>Rereading to monitor comprehension</td>
<td>Re-reading previous pages</td>
<td>Activities related to monitoring activities e.g. as text comprehension is monitored speed of reading is adjusted</td>
</tr>
<tr>
<td>Activities are related to monitoring activities e.g. as text comprehension is monitored speed of reading is adjusted</td>
<td>Slowing pace of reading for more difficult or less familiar text</td>
<td>Returning to previous diagram</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Reviewing any aspect of materials</td>
<td>Skipping forward as material is familiar</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Skipping material and returning later (Pintrich and Schrauben 1992)</td>
<td>Comparing a current diagram to a previous version showing less information</td>
<td></td>
</tr>
</tbody>
</table>

### Table 4: Examples of Orientating and Executing from the Data

<table>
<thead>
<tr>
<th>Metacognitive Learning Strategy/Skill</th>
<th>General Skill</th>
<th>Subordinate Categories</th>
<th>Activities within the data</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>I skipped this part because I already know it</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Cutting and pasting to Notepad software</td>
</tr>
</tbody>
</table>
Table 5: Examples of Evaluating and Elaborating from the Data

<table>
<thead>
<tr>
<th>Metacognitive Learning Strategy/Skill</th>
<th>General Skill</th>
<th>Subordinate Categories</th>
<th>Activities within the data</th>
</tr>
</thead>
</table>

Conclusion

A number of lessons were learned from this trial of both the methodology and data analysis. Firstly, it is clear that in the future it will be necessary to pay more attention to discriminating between the cognitive and metacognitive activities when collecting data, particularly in the stimulated recall component of the methodology. The data were rich in both cognitive and metacognitive processes related to particular interactions with the hypermedia, but it was not always possible to make a clear determination about whether some processes were merely cognitive or, on the other hand, if they involved metacognitive control or monitoring of cognition.

Secondly, a reliable and valid way of correctly classifying the metacognitive activities is needed. Meijer et al. (2006) pointed out in their work that in order to achieve correspondence between judges scoring and metacognitive activities in thinking-aloud protocols the taxonomy needed to be not too detailed.

Finally, although the taxonomy adopted in this work was developed initially to examine text-studying and problem-solving activities in history and physics, the current analysis provides some support for its generalisability. As argued earlier, when learners interact with hypermedia, two important aspects of these interactions are: (i) the learners capacity to effectively relate to the text, and (ii) the learners capacity to make choices about the navigational pathways within the hypermedia they will use to advance their learning (a specific form of problem-solving).

This small pilot study has demonstrated that the methodology appears to be sound and with further refinement should prove a useful tool. However, more work needs to be done on how to more reliably and validly classify the metacognitive activity derived from the protocol analyses, and data from a broader range of hypermedia learners is necessary in order to build a more valid case for the generalisability of the taxonomy of metacognitive activities. Nonetheless, this pilot study has been an important component of a longer term project that seeks to better understand the capacities of web-based learning materials to engage learners in various kinds of cognitive and metacognitive activities. Illumination of the cognitive and metacognitive processes is critical to both improving hypermedia design and to extending the theoretical understanding of learning with this medium.

References


**About the Author**

Fred Beven

Fred Beven has had twenty-five years experience as a vocational educator and educational administrator within the Queensland TAFE system and fourteen years experience as a teacher and researcher in Vocational Education at Griffith University. His research interests include the cognitive aspects of the acquisition of vocational knowledge. The development of technical expertise in hypermedia learning settings has been the focus of his recent research, particularly how different kinds of settings press for different kinds of cognitive activity. Current studies are examining the role of hypermedia structures in developing different kinds of knowledge. Fred was a former editor of the Australian Vocational Education Review.