Direct from the source: the value of 'think-aloud' data in understanding learning

Kirsty A. Young
University of Technology, Sydney

Abstract

The use of verbal data to supplement data obtained through other research methods has been found to provide extensive insights that are not evident when one removes the student voice. This paper examines the use of the think-aloud method to collect relevant and useful data and to enhance data collected through other research methods. It provides an overview of the method and discusses its limitations. This paper also examines the analysis of data produced from think-aloud protocols and concludes with illustrative examples of think-aloud data collection and analysis from a study into Web-based learning.

Introduction

In contributing to our ever-growing understanding of student learning researchers in education recognise the value of observations of students while they work, examination of work samples, evaluation of assessment data and questioning of students, their teachers and caregivers. These four broad forms of data collection are most prevalent in educational research. One area that I suggest is under-utilised is that of listening to the students articulate their thoughts while they engage in practical activity, that is, the collection of think-aloud data. I believe going directly to the source of information (ie. the students) and capturing what they verbalise, provides substantial information to both support and enhance that which we obtain using other common research methods. It also offers the opportunity for student voice to be heard, a voice often neglected in research.

This paper explores the use of think-aloud data and demonstrates the value of such data when researching in the area of Web-based learning. The paper commences with an overview of the think-aloud approach and contrasts its usefulness with that of other methods of collecting verbal data. It then moves to explore the types of activities which lend themselves to the collection of think-aloud

data and raises some of the limitations of this method. This is followed by discussion on the subjectivity of this method and analysis of data collected. The paper concludes with an example of application of this method of data collection in a study I am currently undertaking into Web-based learning.

What is think-aloud data?

Capturing think-aloud data requires the research participant to continually speak aloud the thoughts in their head as they work. The input from the researcher during this process is generally limited to prompts such as "keep talking" if the participant falls quiet for an extended period of time. The participant's thoughts are generally captured by audio recording and thus provide a permanent record for future review and analysis.

Ericsson & Simon (1993), who have been instrumental in the development of this approach, suggest that while participants complete a given task the think-aloud approach is capable of capturing what is held in the short-term memory. This results in a sequence of thoughts that reflect what occurs cognitively during completion of a given activity.

Verbal data capturing human thoughts can be collected at various points and is referred to in the literature as talk-aloud data, verbal protocols or verbal reports. Generally, think-aloud data is that which is collected while the participant is in the process of attending to information. However, researchers can also engage in:

a) concurrent probing – asking direct questions while the participant is undertaking an activity to access information which is held in the participant's short term memory; or

b) retrospective probing where questions are asked after completion of the given activity (Ericsson & Simon 1993).

For the purposes of this paper, think-aloud data refers to talk that is produced continuously throughout the participants' engagement with an activity, rather than only at selected points during the activity, at the conclusion of an activity or during video-stimulated recall.

As shall be explored throughout this paper the think-aloud method is more appropriate for certain research purposes. When considering the potential of think-aloud data the following points should be considered:

1. the aim is to capture what the subject is actually doing;

2. the data will be used to provide a source of insights during the early phases of investigation of a behaviour;

3. analysis of the data will commence from a point where the referents are unknown, rather than confirm or contrast known entities (Chi 1997; Payne 1994).

Hence, the think-aloud approach is particularly useful in uncovering new or emerging phenomena, rather than testing or confirming what is already known.

Appropriate activity design

Fundamental in a researcher's decision to utilise think-aloud data is consideration of the type of activity upon which their research is focused. Payne (1994, p. 247) poses the question: "Are some tasks better suited to be studied using verbal protocols than other tasks?". He answers, and I concur, yes. He contends that the more a task involves cognitive processes that take more than a few seconds to perform and the more the task involves verbal types of information the more suited they are to think-alouds.

Whilst we must ensure the stimulus activity requires sufficient thinking-time to elicit data, we should also consider features of an activity which are likely to reduce the participant's ability to produce think-aloud data. Branch (1994) suggests problems could possibly arise in eliciting verbal data if:

1. the set task involves a high cognitive load;

2. the information is difficult to verbalise because of its form (ie. visual data); or

3. the processes are automatic for the participants.

It is important to be sufficiently familiar with the current level of performance of the participant/s to ensure an activity set is one which is neither excessively difficult, nor one which they perform with such automaticity they are unable to break it down into its component and sequential cognitive steps. Furthermore, we must consider the individuality of learners and appreciate, like interview subjects, some will be more capable of producing data than others and this is somewhat dependent on their ability to complete the research-based activity.

Advantages of think-aloud data

As identified earlier verbal data can take several forms, such as that which is obtained through concurrent or retrospective probes. Other forms of verbal data also emerge through more naturalistic situations such as peer interactions and through interviews and focus groups. Presented in what follows I discuss the potential of the think-aloud approach in minimising problems associated with these other methods of verbal data collection.

Advantages of think-aloud data over other forms of verbal data collection

One of the major advantages in using concurrent think-alouds is that it reduces problems associated with memory failure which may occur when one waits to collect verbal data at the conclusion of an activity (Wade 1990). Whilst the use of video-stimulated recall to obtain retrospective data are being more commonly utilised, it is likely that a participant's ability to remember what they were thinking at previous point in time, even with stimulus materials, is somewhat limited.

Also, given the use of think-aloud data stems from having a learner engaged in a 'real' activity they produce more reliable results than if asked to report on a hypothetical situation (Wade 1990). The key here is the engagement of the learner in an activity in which they become immersed. This provides the researcher with the ongoing thought processes toward that end point. This is in preference to eliciting data by asking an individual how they would complete an activity, without actually engaging in the activity, which would make accurate verbal data far more difficult to produce.

Other common methods of collecting verbal data include analysis of peer-interactions or student-teacher interactions, both of these serve an important and distinct purpose in qualitative research studies. Certainly, the use of peer-interactions and/or student-teacher interactions ensures an abundance of verbal data are produced but the question arises as to what the verbal data reflect. If one is particularly interested in understanding the cognitive processes engaged by learners in a specific activity or environment, the social interactions which would be intertwined with the verbalisation of thoughts can far out-weigh the cognitive component. The think-aloud approach ensures specific focus is directed to the participant's thoughts, which is useful in both minimising distractions from a participant's sequence of thoughts and also aids the researcher in obtaining data that are most purposeful for their research goals.

Discussion groups and interviews are also undoubtedly useful means of eliciting relevant and directed verbal data but one of their major limitations is the tendency of some participants to give what they perceive as desirable response. It is assumed that during the think-aloud process, when a participant is absorbed in a given activity, the completion of this task will take precedence thus limiting the available cognitive 'space' for the participant to formalise desirable thoughts rather than their immediate thought processes. Also, during interviews and discussion groups issues may arise due to a researcher's inadvertent influence over participants' comments and responses to questions. Although it is common for the researcher to be present during the collection of think-aloud data, it is quite possible that the participant (once demonstrating competence in the ability to talk aloud continuously without prompting) could engage in activities in isolation, thus eliminating this problem.

Advantages of using think-aloud data to support observational data

As we have become more aware of the importance of understanding learning as it occurs in context and during activities which reflect authentic situations it has

necessitated the collection and analysis of, what Chi (1997) calls, 'messy' data, such things as verbal explanations, observations, and videotaping.

I value the 'messy' data that are produced by such activities as thinking aloud. I agree with Ericsson & Simon (1993, p xiii) that concurrent verbal protocols provide a "dramatic increase in the amount of behaviour that can be observed when a subject is performing a task while thinking aloud compared to the same subject working under silent conditions".

Observational data are commonly utilised in qualitative research studies and provide an abundance of descriptive data upon which a researcher can rely. One of the problems associated with analysis of observational data is, however, the interpretation of it. One study that examines this issue is that of Williams & Clarke (2002). Although these researchers did not actually use the think-aloud method what is interesting in this study is the way the data are interpreted when they rely on observations alone compared with the interpretation when the student voice is added. In this instance, the video observational data appeared to suggest a student's off-task behaviour and limited attendance to the task at hand. However, adding student voice to the footage subsequently demonstrated progressive formulation of ideas and, importantly, the student participant subsequently provided evidence of a depth of thinking and higher order level of selective attention than was apparent from the video data in isolation.

The above suggests that we can make our observational data more reliable by adding student voice. This highlights my belief that we often neglect the most useful resource we have available to us when trying to understand student learning, the students themselves.

Limitations of think-aloud data

I am clearly an advocate for the think-aloud approach with a strong belief that its strengths outweigh any limitations. However, being aware of the limitations and problems associated with this method of data collection and subsequently taking account of them in research design and analysis makes me (and others) far more capable of capturing and using the relevant data effectively.

Like all research methods think-aloud data are limited and we must have a clear understanding of what this method can and cannot measure and when it is an appropriate approach to yield data which are relevant and useful (Wilson 1994). Discussed below are the limitations identified with think-aloud data including issues of reactivity, participant's verbal abilities and data validity.

Issues of reactivity

Reactivity refers to three main effects of asking a participant to think aloud. The first relates to the ability of a participant to think and attend to a task at the same time. The second considers the effects of talking aloud during an activity which would normally be undertaken in silence. The third refers to the effect of drawing a

participant's attention to the cognitive processes underlying the task being undertaken.

Some contend that we have a limited short-term memory capacity for talking and attending at the same time (Stratman & Hamp-Lyons 1994, cited in Branch 2000; Wilson 1994). Hence, the ability for some people to work through an activity and talk at the same time may be reduced. Indeed, this is sometimes seen during the think-aloud sessions when participants fall silent during activity completion. I believe, however, that being able to obtain even three or four statements giving us information that would not have emerged had the participant remained silent throughout the entire activity is significant in increasing our understanding of the participants under study.

We must then consider the problem associated with verbalising and hearing one's own voice during an activity usually undertaken silently (Stratman & Hamp-Lyons 1994, cited in Branch 2000). Measures can, I believe, be taken to reduce this effect. As discussed previously, the researcher must ensure the activity being undertaken is one that is appropriate to elicit verbal data. Further, to maximise the comfort of the participant the researcher should ensure the participant is aware who will be listening and for what purpose. Also, allowing time for the participant to practice thinking aloud can be beneficial. I have personally found with a range of Year 3 and Year 5 students (ie. 8 – 11 year olds) that although their statements may be of fact, rather than evidence of 'thinking', and also incomplete at times (issues discussed below), they appeared relatively undaunted by the request to verbalise their thoughts and after several minutes often did so quite naturally.

A further consideration stems from the fact that merely asking the participant to think-aloud draws the learner's attention to certain elements of that task which has the potential to engage their critical thinking of the task at hand to a greater extent than in the non-research situation (Stratman & Hamp-Lyons 1994, cited in Branch 2000). Along a similar vein we must also consider the influence of the actual researcher with respect to any verbal or non-verbal cues which may be presented by him/her either directly or indirectly (Stratman & Hamp-Lyons 1994, cited in Branch 2000). Again, minimisation of this issue requires the researcher to be fully aware of this limitation and take due care with actions and comments or, as suggested previously, allow the activity to be completed privately if the participant has demonstrated competence in continuous verbalisation. It should also be noted that although the learner may be more critically engaged in a task due to the research situation I believe that they are still not capable of producing anything outside the scope of their current knowledge and abilities. So, whilst it may capture the participant performing at their best and most focussed, it is still only capable of capturing the learner's current level of performance and actual sequence of cognitive thoughts.

Participant's verbal abilities

As briefly raised earlier, I have found that participants vary in their ability to produce useful think-aloud data. Along with these issues, there are other limitations

found to exist with respect to the abilities of the participant to articulate thought processes. Indeed, Wade (1990) suggests that students with high-level cognitive development will have available mental capacity to report on thinking. Alternatively, those students who are less capable of thinking about their own thinking will be less capable of reporting on it, and thus the think-aloud data may underestimate their knowledge and abilities. In contrast to the problem identified above (which captured the student performing at a heightened level), it may instead be the case that the data actually underestimates the performance of a learner.

Other researchers have also encountered problems in gaining depth in the data produced. Keys (2000), for example, found that several of her participants engaged in more than 90% of verbatim dictation without further deliberation or reflection. Although these participants may have performed competently and successfully in the activity being undertaken their think-aloud protocols provided no evidence of thought processes being engaged. Both Wilson (1994) and Branch (2000) also comment on the issue of incomplete think-alouds. In particular, Branch (2000) reported that while transcribing 144 think aloud protocols she noticed that some participants had very brief or very procedural think-alouds. Again, although this did not necessarily reflect the participants' abilities in successfully completing a given task, it did severely limit the usefulness of the data collected

These two limitations are problematic but we must remain clear on what the think-aloud data is capable of measuring. It is not a tool designed to test students' abilities or measure their competence; it is instead aimed at uncovering thought processes. Also, if it becomes apparent that an individual participant is clearly incapable or unwilling to produce the desired quality of think-aloud data their participation should be reconsidered. So again I reiterate, although the data collected may be limited to statements of fact or procedure, those cognitive statements that are provided by some participants give us far more than if all participants remained working in silent conditions.

Validity

Not only is reactivity a major concern with think-aloud data, the issue of validity is also raised and we must question whether the information provided by think-aloud data accurately reflects thinking (Crutcher 1994). Consideration must be given to the fact that while the think-aloud is held to tap into the content of consciousness it cannot tap into cognitive processes that never reach consciousness (Wilson 1994). If we consider that only a small subset of information (the contents of working memory) is accessible and available to consciousness some would argue that the data produced is automatically and necessarily limited (Wade et al 1999). This, I consider the real limitation to the think-aloud approach. I have found myself the difficulty in bringing my attention and trying to articulate things that can be done automatically. This is where I have found the use of a combination of data collection methods essential. When one notes in the analysis of data what appears to be a critical moment, a post-activity interview allows the researcher to delve into that moment to gain further insight. The collection of video-observation combined with the audio-data collected through the think-aloud aspect becomes invaluable in

this process. Although the learner may, at times, still be unable to provide further insight, it has proved at times for me to be a useful tool to tap into what may be unconscious during the time the action/behaviour is engaged but can be brought to consciousness when one is specifically asked to discuss the action/behaviour.

A further issue is raised by Crutcher (1994) which leads to the next area for consideration in this paper: whether verbal report data can be treated as objectively as other behavioural data. The discussion now moves to issues of subjectivity and the analysis of these forms of data.

Subjectivity and data analysis

Ericsson & Simon (1993) state the obvious that careful verbatim transcripts of the recorded tapes should be made after collection of verbal data, thus preserving the raw data in as 'hard' a form as could be wished. This approach eliminates problems associated with 'soft' data, as it allows the data to be clearly analysed through coding which is, I believe, is the issue at hand – subjectivity in coding the data.

There are two main approaches to coding data produced using think-aloud protocols and Payne (1994) nicely defines each approach:

1. code instances in which certain types of thought seem to occur within a protocol. The frequency of occurrence of different types of reasoning can then be computed across problem types or individuals;

2. break the protocols up into short phrases or segments. Each phrase should refer to what constitutes as single task assertion or reference by the subject. These segments can then be coded and analysed.

My preference is for the second approach described above. This is similar to the approach of Keys (2000) who suggests transcribing of the data in full and then parse into clause-length segments. The protocol data can then be the subject of interpretive coding. At this level I like to incorporate any video observational footage into the 'hard' data – aligning think-aloud data with physical behaviours to further enhance the coding categories which are emerging.

Interpretive marginal notes can also be made alongside the protocol transcriptions (Miles & Huberman 1994). Coding and categorising in this manner allows the researcher to identify the types of thinking evident in the think-aloud data. In the case of integrated observational and think-aloud data the researcher can compare the verbal statements and actions of participants allowing theory to emerge relatively quickly.

Ericsson & Simon (1993) present analysis along a similar line to that which is espoused above: the encoding scheme is not defined formally, but the search for interpretations proceeds in parallel with the search for an appropriate model or theory. They particularly highlight the value of this interactive process to data analysis in the search for new domains.

Indeed, this approach to data analysis aligns with the original statement of the purpose of think-aloud data where theory is emergent and discovered in the data and, therefore, analysis commences from a point where the referents are unknown, rather than confirms or contrasts known entities.

The use of think-aloud data in a study of Web-based learning

Researchers have reported success with the use of think-aloud data in many varied studies. For example, Keys' (2000) used the approach to analyse 8th grade students' writing processes during science related activities; Wade (2000) in her examination of readers' attempts to construct meaning from text and Weiner (1994) to uncover first grade students' descriptions of how they spell.

Another area of research that I believe will benefit from the use of think-aloud data is that which examines student learning in technological environments. Indeed, it is one of my preferred research methods in my attempt to understand student learning in Web-based environments.

The current nature of research into Web-based learning

The degree to which the Web is being integrated into some communities in the developed world makes it of current interest and importance to many researchers in diverse fields. My personal interest in Web-based learning stems from its nature as a complex and unique learning environment which is being utilised by students both in formal learning situations and leisure. Research in this area has been found to explore many isolated components of learning within this environment (eg. its use in distance learning or a student's search and navigation techniques). Studies have generally relied upon distinctly different research methods given the wide scope of fields interested in Web-based activity. The problem with this varied approach to research design is that it becomes difficult to understand and contrast the impact of Web-based learning environments. This led me to believe that what is needed is some understanding of how the Web affects learners when used in its authentic state, that is, when it is used in the culturally dominant way of regular members of society. My desire was to avoid focusing upon one type of learning experience which can be provided through the Web (eg. online tutorials, problem-based scenarios) but rather have students engage with any or all of the features of the Web as necessary and/or desired to fulfill his/her personal needs and goals.

I see the think-aloud method as an essential tool in research into the field of Web-based learning. At present we do not understand the effects of learning in the Web-based environment and so are not looking to confirm known entities or test specific theories of learning. Rather we need to capture what learners are actually doing in this environment and gain some insight into learners' thinking when engaged with the Web. These are precisely the elements the think-aloud approach is designed to elicit from the research participants, making it such a useful tool for this field of research.

Overview of the research design

My research into Web-based learning aims to identify some of the unique types of learning taking place in this environment, resulting in a profile of the young, competent Web-user.   While my primary source of data collection were think-alouds I also relied upon three traditional methods of data collection to support and enhance my findings:

> a) questionnaires to identify appropriate participants;
>
> b) video-observations of the participants working in context; and
>
> c) post-activity follow-up interviews.

To clarify the research situation, five Grade 5 students were identified as competent Web-users. They were asked to identify their own Web-mediated activity. While completing the independent Web-activity each participant was asked to concurrently think aloud. At this time their actions and words were captured on video- and audio-tape. After preliminary analysis of the observational and think-aloud data the participants were interviewed. At this time they were asked questions and also asked to complete a range of structured activities on the Web. The follow-up interview was designed to elicit more information on issues which had arisen from initial analysis of observational and think-aloud data.

The think-aloud research activity

The use of think-aloud data was essential in my own study to uncover elements of student learning in the Web-based environment. The data would not have emerged, however, if the Web had not provided an appropriate activity to elicit think-aloud data.

As discussed previously several factors must be considered in engaging an appropriate activity to elicit think-aloud data and I attempted to address the factors contributing to appropriateness of a stimulus activity as follows. Although certain facets of the Web are perhaps held as cognitively demanding, the flexible nature of the Web allows learners to pace and regulate their own learning to accord with their current level of understanding and development.   This flexibility, I believe, makes study of Web using think-alouds especially appropriate. Having participants identify their own Web-mediated activity ensured a task they were competent in completing. This aided in directing their focus and reduced problems associated with cognitive demands.

Further, although not necessarily natural to verbalise while using the Web, I personally found that after several minutes of doing so the students appeared to move to 'mumbling' (although generally audible) to themselves about the task at hand which suggested students were absorbed in the activity and talking aloud appeared to have little impact on their performance.

Examples of think-aloud data from research into Web-based learning

I make several claims of the benefit of think-aloud data throughout this paper. In order to substantiate these claims I provide several illustrative examples below. Each of these examples is derived from one research participant, Elizabeth. Her think-aloud protocols were obtained whilst she was using the Web (particularly the Google search engine) to answer several research questions which she devised herself specifically related to the history of field hockey.

I will first discuss a small selection of think-aloud protocols which I believe provide insight into cognitive processes which are being engaged whilst Elizabeth was working in the Web-based environment. Following each think-aloud statement in brackets is my initial interpretation of each statement:

1. *"It says 'go local' so you highlight a country so I am going to click on Australia"*

   (interpretation of graphical representation; awareness of local v. global locations)

2. *"I'm going out of this website because it didn't have any new information that I hadn't already heard of"*

   (evaluating material; monitoring own progress toward learning goals)

3. *"So I've kind of worked out where it was made, where it was created and there's a whole lot of words on the edge, I'm going into 'History and Traditions' and maybe it will say more about it"*

   (monitoring own progress toward learning goals; scanning for keywords)

These think-aloud protocols provide significant insight into Elizabeth's decision-making processes at various levels. They allow for interpretive analysis of her actions to further understand what actually occurs whilst she is engaged in Web-mediated activity.

I also state another main advantage of the think-aloud approach is its ability to enhance observational data. To highlight this advantage I provide several extracts from the video-observational data. Each of the three examples is then followed by integration of the think-aloud data to demonstrate the enhanced analysis that is possible when both sources of data are used.

Video observation

Elizabeth moves mouse over the words on the screen, scrolls to bottom of Google search page and clicks on the final entry on first search page.

Video observations incorporating think-aloud statement/s

Observation	*Think-Aloud Statement*
Elizabeth moves mouse over the words on the screen, scrolls to bottom of Google search page and clicks on the final entry on first search page.	"I'm looking for one that's got like in the little words under the heading, like information, maybe the person's name, or something that seems interesting".

The observational data merely tells us that Elizabeth has entered the final entry on the first search page. By adding her voice we are under no doubt as to what Elizabeth is looking for in the Google search results and subsequently her underlying decision for entering a Website. Her think-aloud statement indicates that she is focused on identifying information relevant to her topic of interest and she knows how to utilise the search features (ie. blurbs describing each Website in search results) effectively.

Similarly, in the second example, we have Elizabeth's voice to confirm assumptions we may have made from observation alone.

Video observation

Elizabeth enters Website. Before page has fully loaded she uses the 'back' arrow on the Internet Explorer navigation bar to return to her Google search results.

Video observations incorporating think-aloud statement/s

Observation	*Think-Aloud Statement*
Elizabeth enters Website. Before page has fully loaded she uses the 'back' arrow on the Internet Explorer navigation bar to return to her Google search results.	"It's coming, very slowly ... it's taking a while … I don't like that site it's not coming".

Elizabeth's decision not to enter the chosen Website has been made clear. She prefers Web pages that load quickly and does not demonstrate the patience to wait for pages that reveal more slowly.

In a final example, we gain another insight into her understanding of the Web, in this case the limitations of the tool when searching for specific information.

Video observation

Elizabeth highlights the words in the Google search box and removes the words "who created" from her original search criteria of "who created field hockey".

Video observations incorporating think-aloud statement/s

Observation	*Think-Aloud Statement*
Elizabeth highlights the words in the Google search box and removes the words "who created" from her original search criteria of "who created field hockey".	"I'm going to change the thing I put in at the start. I think there was probably too many words in there and it didn't understand what I was asking".

In this instance we do not need to make assumptions behind Elizabeth's problem solving process when trying to obtain specific information. Instead her statements make it clear that she is aware that the searching tool is limited in its ability to interpret her question.

Although brief, I believe the above demonstrates the true strengths of this research method. The examples clearly show that by adding student voice we can:

1. uncover usually covert cognitive process, such as decision making; and

2. eliminate assumptions in our analysis of observational data.

Conclusions

The limitations of the think-aloud method of data collection are thoroughly explored in this paper. It is essential for one who desires to use this method of data collection to be fully informed of these limitations in order to elicit useful, relevant and sufficient data. However, I firmly believe that what is added to the research data through the use of this research method far outweighs these stated limitations. I concur wholeheartedly with Wilson (1994) that while it is not claimed that think-aloud data provides a complete insight into the human mind, it certainly is a useful tool available to the researcher.

Clearly, relying on the student as a direct source of information minimises a substantial amount of guesswork that is necessary when we are observing behaviours and/or conducting analysis of the final product presented by a learner.

With respect to investigations into learning in Web-based environments I consider the approach particularly important while we are in the process of trying to gain insight into a relatively new phenomenon. This is especially so as we, a generation of researchers who did not 'grow-up' with the availability of the Web, attempt to interpret behaviours with which we may not be familiar or not expect. Indeed, we risk completely misinterpreting or overlooking behaviours of learners who are competent Web-users and have known no life without access to the Web.

For any researcher who develops an understanding of when thinking aloud is appropriate and carefully considers the activity used to elicit such verbal data the

rewards will certainly be evident through the enhanced data which the student voice provides.

References

Branch J L (2000) The Trouble with Think Alouds: Generating Data Using Concurrent Verbal Protocols. *CAIS 2000: Dimensions of a Global Information Science*. Canadian Association for Information Science Proceedings of the 28th Annual Conference.

Chi M T H (1997) Quantifying Qualitative Analyses of Verbal Data: A Practical Guide. *The Journal of the Learning Sciences*, vol 6, no 3, pp 271-315.

Crutcher R J (1994) Telling What We Know: The Use of Verbal Report Methodologies in Psychological Research. *Psychological Science*, vol 5, no 5, pp 241-242.

Ericsson K A & Simon H A (1993) *Protocol Analysis: Verbal Reports as Data*, Revised Edition. The MIT Press. London.

Hess B (1999) Graduate Student Cognition during Information Retrieval Using the World Wide Web: A Pilot Study. *Computers & Education*, vol 33 no1, pp1-13.

Keys C W (2000) Investigating the thinking processes of eighth grade writers during the composition of a scientific laboratory report. *Journal of Research in Science Teaching*, vol 37, no 7, pp 676-690.

Land S M & Greene B A (2000) Project-based learning with the World Wide Web: A qualitative study of resource integration. *Educational Technology, Research and Development*, vol 48 no 1.

Leblanc S, Saury J, Seve C, Durand M, Theureau J (2001) An analysis of user's exploration and learning of a multimedia instruction system. *Computers & Education*, vol 36 no 2, pp 59-82.

Miles M B & Huberman A M (1994) *Qualitative data analysis: an expanded sourcebook*. Thousand Oaks: Sage.

Payne J W (1994) Thinking Aloud: Insights Into Information Processing. *Psychological Science*, vol 5, no 5, pp 241-248.

Wade S E (1990) Using think alouds to assess comprehension. *The Reading Teacher*, vol 43, no 7, pp 442-451.

Wade S E, Buxton W M & Kelly M (1999) Using think-alouds to examine reader-text interest. *Reading Research Quarterly*, vol 34, no 2, pp. 194-216.

Weiner S (1994) Four First Graders' Descriptions of How They Spell. *The Elementary School Journal*, vol 94, no 3, pp 315-330.

Williams G & Clarke D (2002) The contribution of student voice in classroom research. *South African Association for Research in Mathematics, Science and Technology Education Conference*, University of Natal, Durban, South Africa, pp 398-404.

Wilson T D (1994) The Proper Protocol: Validity and Completeness of Verbal Reports. *Psychological Science*, vol 5, no 5, pp 249-252.

Yang S C (2001) Multidimensional taxonomy of learners cognitive processing in discourse synthesis with hypermedia. *Computers in Human Behaviour*, vol 18 no 1, pp 37-68.