Video Analysis: A qualitative tool for investigating students' learning in a constructivist-oriented multimedia in a science classroom

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A new software package VideoSearch which is a Macintosh multimedia research tool for analysing digital video was used to analyse classroom observations. VideoSearch can digitise video from a video cassette recorder or video camera and store it on a computer as a QuickTime movie. Texts can be attached to each instance within an episode and this text can be searched. Episodes in this movie can then be coded for analysis by means of user defined categories. Analyses of three types of episodes from video segments are presented and discussed in order to investigate students' learning. Episodes from video segments include students working in pairs conducting investigations based on an inquiry-based multimedia program, students presenting their experiences of their process of investigation and the researcher probing the students' reflections on their learning during an interview. An advantage of working with the digital video analysis is a greater access to a fuller context for qualitative data analyses. This allows for a better understanding of the social processes of students' learning. However, the time required and the level of intensive analysis may make it a difficult process to undertake.

Rationale

Identifying the process by which higher order thinking skills develop requires appropriate tools and strategies. However, appropriate identification of students' thinking skills also requires clear definitions of the constructs to be identified (Ennis, 1993; Lewis and Smith, 1993). Lewis and Smith (1993) define higher order thinking as:

> [T]hinking [which] occurs when a person takes new information and information stored in memory and interrelates and/or rearranges and extends this information to achieve a purpose or find possible answers in perplexing situations (p136).

Higher order thinking involves inference, interpretation, analysis, judgement, active mental construction and synthesis (Resnick & Resnick's, 1992; Newman, 1990). Research suggests that higher order thinking may be enhanced when students are actively engaged in critical reflection within a meaningful context (e.g., Blanton, Moorman & Trathen, 1998). In a constructivist-oriented inquiry-based learning environment, small groups of participants engage in critical reflection and collaboratively determine a problem, generate creative questions and design investigations accordingly (Maor & Taylor, 1995) in meaningful contexts.

An inquiry-based learning environment may be well supported by the use of interactive multimedia which promotes small group work involving specific interactions and scientific investigations. The essential features of such multimedia include:

- Provision of multiple representations of reality;
- Representation of the natural complexity of the real world;
- focus on knowledge construction;
- presentation of authentic tasks; and
- support for the collaborative construction of knowledge through social negotiation (Maor & Phillips, 1996).

Identifying the use of higher order thinking skills

Videotaping student interactions in an inquiry-based interactive multimedia learning environment provides a means by which to identify the use of higher order thinking skills. An adaptation of Ennis' (1993:180-181) "purposes of critical thinking assessment" was used in this study as a framework to analyse of the data. Social negotiation between pairs of students provided ongoing and immediate feedback on the students' higher order thinking skills. Open-ended challenges were provided during interactions with the program and curriculum material which included a guide to the program and questions based on its content. A presentation by pairs of students to the whole class informed the teachers and other students of the extent to which participants were successful in using their higher order thinking skills. This activity also allowed teachers to identify the appropriate student outcomes within the science curriculum learning area (Maor, 1998). The use of the inquiry-based interactive multimedia program also provided information for further research into student learning and development of higher order thinking.

Advantages of using an inquiry-based interactive multimedia program

Using an inquiry-based interactive multimedia program promotes social constructivist learning (Maor & Taylor, 1995; see also Tobin, 1993) in the classroom. In this socially constructed learning environment, students are able to negotiate their learning pathways each time they use the program while collaborating with each other thus taking control of their learning and challenging and extending their higher order thinking skills. Social negotiation provides frequent feedback to students about their communication with each other and their understandings of the process of scientific investigations and the content of the program. This may also facilitate cross-cultural communication within the context of the science classroom. In this socially constructed learning environment, the progam, used in a collaborative context, also supports the development inquiry skills (Maor & Taylor, 1995).

Aim of the Study

The aim of this study was to explore the use of an inquiry-based interactive multimedia program to identify the process by which students' higher order thinking skills developed in a science classroom. Classroom sessions were video taped to allow in-depth analyses of interactions between pairs of students while they used an inquiry-based interactive multimedia program. In this paper analyses of three types of episodes involving one pair of students from the study are presented. These episodes include two students:

- conducting collaborative investigations based on the multimedia program;
- presenting their experiences of their process of investigation; and
- the researcher probing the students' reflections on their learning during and interview.

Methodology

Erickson (1998) provides a methodological link between an inquiry-based classroom learning environment and the process of research to identify the students' use of higher order thinking skills. The methodology suggested by Erickson (1998, p1155) enabled the researcher "to identify the nuances of subjective understanding that motivate various participants in a setting [such as a school classroom and] to identify and understand change over time" across two collaborative investigations. Both the subjective understanding of student motivations and changes in thinking skills over time have been found to be significant in the development of higher order thinking skills (Ennis, 1993; Lewis & Smith, 1993)

Twice each week during the month following the initial investigation, students interacted with each other and the multimedia program. Video taping of classroom interactions provided a means of analysing students' thinking skills within the rich context of the whole classroom learning environment. Analyses of the video data were facilitated by the use of the VideoSearch program (Knibb, 1997). Trustworthiness of the data was enhanced by the use of VideoSearch (Knibb, 1997) program as it enabled the long-term storage and retrieval of indexed data for analyses and an efficient and effective audit trail. This offers the potential to provide a ready means of reaccessing the data by the researcher for presentation and critical review by colleagues to ensure credibility of the data, the analyses and interpretations. Information about the process of students' learning while generating collaborative scientific investigations can thus be transferred and applied to other students in the same classroom and across different classrooms and schools.

VideoSearch

VideoSearch is a Macintosh computer program designed to allow researchers to identify, categorise and describe digital video on the desktop of their computers. The first part of the process in using VideoSearch is to connect a VCR or video camera to a Macintosh with a digitising card. Next, an analogue movie is recorded and saved as a QuickTime movie on the hard drive. VideoSearch then displays the *Movie* (see Figure 1) in a window. Approximately one hour of useable video can be stored for each gigabyte of hard disk space, but this varies according to the quality of the images required.

Figure 1: QuickTime movie window

Next, VideoSearch creates and links a code window (see Figure 2) to the QuickTime movie window (see Figure 1). The code window is where the researcher can create categories, instances and descriptions that refer to the movie window. This code window provides a visual representation or profile of coded events in a video episode. Figure 2 shows six categories in a list, beginning with *Category A.* An *Instance* has been inserted in rows 1 and 2 for *Categories A* and *B* respectively. Descriptions of each *Instance* have also been inserted in these rows. There is no effective limit to the number of categories and instances which can be created. However, there is a limit of 5000 words which can be used to describe each instance.

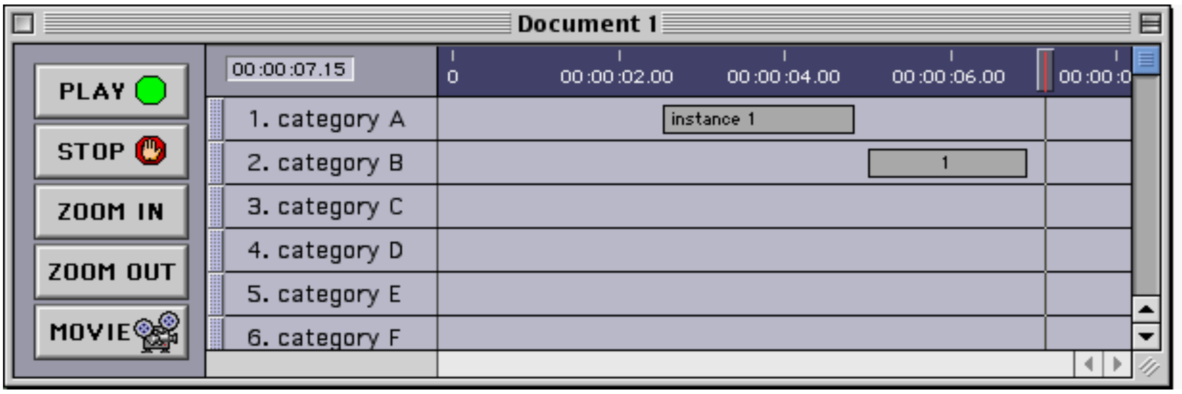

Figure 2: Code window which VideoSearch links to the Movie window

There are a number of potential advantages in working with digital video on a computer compared to conventional storage on analogue tapes. One advantage is that when digital video is stored on a computer's hard disk, the time required to shift from one time in the video to another is almost instantaneous. The time taken to access a movie segment or episode that is two minutes from the start of the video, is the same time it takes to access a segment one hour into the video. This technology means that video instances from any part of the digital video can be combined and played as a single continuous movie segment or episode and connections can be made between events separated by time. Individual instances of a video segment or episode can be reviewed by double clicking on the target *Instance* in the code window. The full description for an individual *Instance* can then be viewed in a text window simultaneously with the connected video segment.

In this paper, a case study of one pair of students, Louise and Elise, is presented. The students' learning is analysed during their interactions with each other while using an inquiry-based interactive multimedia program, *Birds of Antarctica* (Maor & Taylor, 1996), during a presentation to the whole class and in an interview about their experiences. Episodes were created from segments of video which comprised self-contained interactions between students and/or the multimedia program and/or the researcher. Together, these episodes provide a broad and a contextualised perspective on the development of higher order thinking skills.

Analysis of the data

Overview of the VideoSearch data display for this study

An investigation undertaken by the students, a student presentation and a student interview each constituted one episode. The digital movie shown in the top right hand corner of Figure 3 is a combination of two movies. The left-hand side of this movie shows what part of *Birds of Antarctica* (Maor, 1996) the students were viewing at a particular time. The right hand side of the movie shows a synchronised view of the students interacting with each other and the multimedia program. These movies were digitised separately, then joined together to form a single digital movie with the two views of events occurring at the same point in time.

Figure 3: An example of a general VideoSearch display of the collated data

Prior to selecting specific episodes for analysis, the researcher viewed several times, fifteen hours of video taped classroom observations. During subsequent viewing of and listening to selected episodes, the researcher coded the data as displayed in Figure 3. Coding this episode included establishing observed categories, deciding the length for each instance and viewing, transcribing and writing the description for each instance. This required around four hours for fourteen minutes of observation time. The coded categories (e.g., generate a question, hypothesis, etc.) for a single episode appear in a separate code window under the relevant QuickTime movie. The categories presented in Figure 3 constitute the components of a scientific investigation. While generating each of these categories, the researcher identified chronological instances of those observed categories. The initial text of these instances appears to the right of the categories in Figure 3 with the duration of the instance identified by the length of the box. Each of these chronological instances consists of the description of that instance (e.g., dialogue between the students and some researcher comments).

In this study, coding categories based on inquiry learning were developed prior to the video analysis. Additional categories were developed while the researcher viewed the video segments and were based on student interactions with a constructivist-oriented multimedia program. From the general display of the collated data, the researcher was able to focus on and profile specific investigations by two students.

Profiling simple and complex investigations

A profile is a visual representation of the process of a scientific investigation. Initially, profiles of student investigations were relatively simple, for example, Investigation I by Louise and Elise as displayed in Figure 4.

Figure 4: Complete VideoSearch display of collated data for Investigation I by Lousie and Elise

In this episode, Louise and Elise generated a brief scientific investigation which contained only one category, *Inquiry*, directly relating to the process of scientific investigation. Other categories included *Technical Problems* which were outside the control of the students and included hardware and software problems such as the computer freezing and limited memory which resulted in slowness of the software. A third category, *Improving Methods*, consisted of interactions during which Louise and Elise learned how to use and navigate the program more effectively. A fourth category, *Writing the Investigation*, consisted of the students completing a report of their investigation from the supplied curriculum support material. For example, *Instance #1* for *Improving Methods* (see "Use of" highlighted in Figure 4, revealed that Louise and Elise were able refine the presentation of their data by using a graph instead of a table. The description for the "Use of" box in Figure 4 are displayed when the box is double clicked. The description for this box is shown in Figure 5.

Investigation I

Improving Methods: Instance #1

(Index: 3:31 - 4:06 minutes; duration: 35 seconds)

Use of graph to improve data display

Louise is dominant. Louise came up with a new idea how to use the graph instead of presenting the data in a table.

Louise: You don't even to need to collect the information at all. You put the species Adelie Penguin and it came with 37, in and it come up with the number and then you can do the graph straight away of bird behaviour...

Elise: ... and now instead of looking at all the voyages we will do the right course.

Figure 5: The description in the text window *from Improving Methods: Instance #1* for Investigation I by Louise and Elise

However, the complexity of profiles for investigations increased over time. More efficient use of the multimedia program was reflected in more complex designs of investigations with each subsequent use of the program. These changes are evident when Investigations I and II are compared (see Figures 4 and 6).

Figure 6: Complete VideoSearch display summary of collated data for Investigation II by Lousie and Elise

The complexity of the visual profile for Investigation II in Figure 6 readily contrasts with the relatively simple visual profile for Investigation I in Figure 4. The more complex visual profile for Investigation II was created by an increased number of observed categories, up nine to

13, from four in Investigation I. On-task interactions between the students and the multimedia program increased over the month from 7:48.79 minutes during Investigation I to 26:25.00 minutes for Investigation II. Similarly, the content of interactions in each instance of observed categories was more elaborate and the duration of the instances increased during the same time (see Figure 7).

Investigation II

New Investigation: Instance #2

(Index: 12:03 - 15:40; duration: 3 minutes 37 seconds)

Both students jointly conducted the investigation.

Louise suggested the idea followed by Elise who explained the concept on which they were working.

Louise and Elise swaped between screens.

Dorit (researcher): What are you doing now?

Louise: Making a histogram of sea state and...

(some negotiation between the girls about the selection of variables)

Elise: The ice berg will show on the graph.

Louise agreed: We'll choose a variable of sea state against the frequency to see if the sea state affects the number of ice bergs.

The program generated a graph but the students didn't stop to discuss it.

The TOTAL PHYSICAL OBS. axis on the graph confused Elise.

Louise: We need to make two different graphs.

Dorit: You can select scatterplot.

Meanwhile, they selected another variable, sea ice and got a different graph, a histogram with three bars. They found it difficult to interpret the graph and Louise continued to design a scatterplot. Louise then selected *Ice berg* against *Sea State*

Louise: Now we can see if there is a strong relationship... so all the dots will be together.

Figure 7: The full description of *New Investigation: Instance #2*, one instance within Investigation II by Louise and Elise

After having interacted with the program for one month, student pairs presented their experiences of conducting the investigations to the whole class. This exercise provided further data about students' use of higher order thinking skills as they were required to reflect on their experiences.

Student presentations

After one month of using the program, student pairs presented one example of an investigation to the whole class. At the introduction of this presentation, Elise chose to reflect on her work and chose to compare it with her experiences of conducting science investigations in a more didactic learning environment with which she was more familiar. Viewing her presentation using VideoSearch allowed the researcher to chronologically index and extract specific information. For example, for the observed category, *Presentation,* the following instance, *Instance #1* commences at 3.82 seconds into one episode on the video. In this instance, Elise expressed her reflections by comparing her experiences in the inquiry-based interactive multimedia learning environment to those in the real world:

> Elise: In the real world... let's say we have to do something in Biology, we will have lots of information, different ways of collecting it, different ways of graphing it and collating it, different ways of showing it and collating it.

(*Presentation: Instance#1*; Index: 3.82 seconds).

VideoSearch further enabled the researcher to chronologically locate a later comparison made by Elise. In this comparison, Elise considers how her experiences over the previous month compared with her usual experiences in the science classroom:

> Elise: That sought of taught us how to do that... taught us how we needed to make decisions in order to get the best result we could. As in the classroom we were given the straight thing, its like the exercise that already set for us, we have the info we are told how to use it. All you have to do is do that, what's written down.

(*Presentation: Instance#*2; Index: 17.19 seconds).

An even later instance in which Elise compared her previous month's experiences as a learner in a novel learning environment was also able to be chronologically located and connected with the two earlier comparisons to provide a more contextualised overview of Elise's reflections:

> Elise: It's sought of developing different skills... made us think more about it, and you are more interested in it all because you made more your own decisions (*Presentation: Instance #3;* Index: 34.15 seconds).

Such reflections have been shown to be essential in the development of higher order thinking skills (Ennis, 1987). The fact that the previous month's experiences in the science classroom working with the program resulted in quite deep and spontaneous reflections about her own learning augurs well for the development of her higher order thinking skills. Being able to chronologically index and retrieve each of these instances enables the researcher to provide highly contextualised, in-depth insight into her thinking which is not available when using other qualitative data analysis tools currently available. Further insights were gained through an interview with the students after they had been working with the program for one month.

Student Interview

To probe students' higher order thinking, an interview was conducted with Louise and Elise. The questions put to the students were based on theoretical understandings of the constructs of higher order thinking (see Resnick & Resnick, 1992; Newmann, 1990). Observed categories and instances of those observed categories show the students' knowledge and reflections on their use and development of higher order thinking skills (see Figure 8).

Figure 8: Observed categories for the students' interview

While the students did not explicitly articulate their development of higher order thinking, the way they expressed their experiences showed they were using and had developed those skills over the month. The students demonstrated a developing sense of inference, interpretation, analysis, judgement, active mental construction and synthesis, all of which are essential elements of higher order thinking (Resnick & Resnick, 1992; Newmann, 1990). When asked during the interview to reflect on their own learning, the students chose to focus on the process of the scientific investigation rather than the content of the program:

> Dorit: What did you learn from the program?
>
> Louise: How to conduct an investigation.
>
> Elise: How to go about collecting information.
>
> Louise: Yeah, what information was needed specifically for a question
>
> Elise: Breaking down the question to find out what you needed in order to answer it and going and finding out and then how you followed it up... access information.
>
> (*Reflection about your own learning: Instance #1*; Index: 1 min 2 3.69 seconds)

In the above instance, the students demonstrated skills in interpreting and analysing the question and making judgements about the relevance of available information. Further into this instance, when asked by the researcher whether they usually did these things in their science classroom, Louise and Elise highlighted how the process of scientific investigation enabled them to focus on the content of the program to answer the question:

> Dorit: Do you usually do these things in science?

Elise: Y-e-s, we did those but not so specific, (looking at Louise)

Louise: No it's different. Here you have the questions and you have to break it down, to see what information you need. But if you look at the question you might think I need *environment* and *sea* conditions but when you look at the map and do it you need more information than that. So you can see from looking at the map you need *iceberg* and everything else to do with it.

Elise jumping in. Both girls look enthusiastic and volunteered information.

Elise: In the classroom they give you an aim and methods... but here you have to find out your own way to answer the questions.

Dorit: Did you have a feeling of scientific investigation here?

Elise & Louise: Yes, we did.

(*Reflection about your own learning: Instance #1;* Index: 1 min 50.69 seconds*)*

Students' found working together supported their learning by providing multiple perspectives on the investigation:

Elise: ... you can talk and get different points of view.

(*Working together: Instance #;* Index: 5 mins 14.58 seconds)

Students also engaged in active mental construction of the designing and conducting scientific investigations based on the multimedia program:

Louise: You've got to do it all by yourself. You haven't got the question, hypothesis and so on. So you have to think about your questions. You think of variables, and data to collect.

Dorit: There is a lot of your input and involvement in the program?

Elise: You are actually happy when you're doing it. When you're doing it then you understand it better.

Dorit: Then, was it your own input more than what the program gave you?

Louise & Elise: Yes.

(*Program helped to think: Instance #1*; Index: 6 mins 20.39 seconds*)*

Inferential thinking was also evident in Louise and Elise's reflections and actions during the interview:

Dorit: Yourself as a learner... What's going on inside your mind?

Elise: ... you have to think about each step before you doing something, think about where it is going to get you and is it going to answer my question? Is there a better way to do it? Is there a quicker way? Maybe more effective? So you think about it this way.

Louise jumping in impatiently.

Louise: When you get a question you go straight into something, and don't think about other options. If there's an easy way of doing it, we wouldn't think about it.

Elise: Both times we collected a lot of data and found later that we could just go into the graph.

(*Yourself as a learner: Instance #1*; Index: 2 mins 43.35 seconds)

After having experienced a trial and error approach to scientific investigation and, according Louise, not having considered other options, Elise emphasised they had learned to judge and to think about each step in the process before they began it. They began to look for "better", "quicker" and "more effective" ways to conduct investigations, something they had not previously attempted. This demonstrates a wide range of higher order thinking skills which was directly enabled by the use of the inquiry-based interactive multimedia program while working co-operatively with another student. Students reflected on the nature of the program, the process of their own learning, and their perceptions of themselves learners

Discussion

When students presented their investigations to the whole class, the role of higher order thinking skills became evident. Through reflecting on their experiences, students were better able to make inferences about the information provided, to interpret new information about the program and its content, to analyse available information, make judgements about its relevance and synthesise what they had learned to generate new knowledge about the Antarctic environment. The development of higher order thinking was even more evident during an interview with the two students who were able to articulate their own thinking strategies. After probing by the researcher, they were able to think about themselves as learners and clearly able to reflect on their own learning which they found intrinsically motivating. Working co-operatively was fundamental to the whole process and appears to have enhanced the students' abilities to use higher order thinking skills and to reflect on that use.

Students were able to generate questions as part of a scientific investigation through social negotiation with their partners. It seems that the reason for the difference stemmed from the planning for social negotiation as an integral part of the learning environment. The researcher interacting with the students was as important as the students working together, negotiating and co-operating while interacting with the program. This is evident in the type and number of categories present during the second investigation but absent in the first investigation. In previous studies in this area by Maor (1993) and Maor and Taylor (1995) social negotiation occurred on an ad hoc basis. It was noticed that during infrequent social negotiations students asked more creative questions during investigations. This observation led to social negotiation being actively planned for in the current study. Compared to the earlier research, students in this study were able to generate more relevant and complex questions.

The initial scientific investigation conducted by the students in this study, was based on their limited inquiry skills (e.g., answering a question from curriculum materials, collecting data, improving methods of data collection). However, subsequent investigations revealed more complexity and more variety in the students' range of inquiry skills (e.g. generating a question, generating and verifying an hypothesis and designing and investigation). This suggests students progressed from low levels of inquiry skills to higher level skills during the study.

The multimedia program, by providing multiple representations of reality and the natural complexity of the real world, enabled students, working collaboratively, to focus on knowledge construction while conducting authentic scientific investigations. Video taping students interactions while conducting scientific investigations using the multimedia program provided a means for better understanding the context of the social processes of students' learning.

The researcher's previous experience in conducting interpretive research involved analysing data essentially removed from the full context in which it occurred despite thick description and using triangulation (Guba & Lincoln, 1989; Erickson, 1986). With the time required to analyse qualitative data, there is a risk of losing or distorting both the data and its interpretation thus reducing the trustworthiness of the research (Guba &Lincoln, 1989). This situation is created by a reduced number of dimensions which is necessary to maintain control over the data. These fewer dimensions can then be coded for subsequent analyses. However, with digital video analysis it is possible to code and analyse multiple dimensions in the data (e.g., dialogue, researcher comments, etc). Digital video analysis allowed the researcher to more finely tune the data analysis and therefore extend the researcher's claims while ensuring greater accountability.

However, the time required and the level of intensive analysis may make digital video analysis a difficult and expensive process to undertake in its current form. For a researcher to be able to use the program effectively they would need to devote the time required, to learn digital video coding techniques, have access to sufficient disk storage space and be able to use a digital video camera. If it is possible to overcome these limitations, being able to zoom in on and analyse very small episodes of students' learning means researchers can access and analyse additional dimensions of students' learning. Future researchers could also focus on dimensions not addressed in this research, for example, the role of non-verbal communication in student learning in the classroom. This study has provided an initial profile of a scientific investigation and provides a means for researchers to develop a corpus of profiles of investigations. This may help teachers and teacher educators to bridge the gap between theory and practice in the science classroom.

References

Blanton, W. E.; Moorman, G. & Trathen, W. (1998). Telecommunications and teacher education: A social constructivist review, *Review of research in education, 23,* 235-275.

Ennis, R. H. (1993). Critical thinking assessment, *Theory into practice, 32*(3), 179-186.

Ennis, R. (1987). A taxonomy of critical thinking dispositions and abilities, *Educational Leadership, 43,* 44-48.

Erickson, F. (1998). Qualitative research methods for science education, In B. J. Fraser & K. G. Tobin (Eds.),*International handbook of science education* (pp. 1157-1173), Dordrecht, The Netherlands: Kluwer.

Erickson, F. (1986). Qualitative methods in the research on teaching, In M. C. Wittrock (Ed.). *Handbook of research on teaching* (3rd edition), pp119-160, New York: Macmillan.

Guba, E. & Lincoln, Y. (1989). *Fourth generation evaluation,* Newbury Park, Calif.: Sage Publications.

Knibb, K. (1997). *VideoSearch:* Software package, Perth: Vigital.

Lewis, A. & Smith, D. (1993). Defining higher order thinking, *Theory into practice, 32*(3), 131-137.

Maor, D. (1998). Birds of Antarctica and the Curriculum Framework. *SCIOS: Journal of the Science Teachers' Association of Western Australia*. *33*(4), 21-22.

Maor, D. (1993). *An interpretative study of the development of students' inquiry skills in a computerised classroom environment from a constructivist perspective,* Unpublished doctoral dissertation, Curtin University of Technology: Perth, W.A.

Maor, D. & Phillips, R. (1996). Developing a multimedia package for teaching thinking skills, In C. McBeath & R. Atkinson (Eds.)*, The 3rd international interactive multimedia symposium 1996* (pp. 242-249), Perth: Promaco Conventions.

Maor, D. & Taylor, P. C. (1995). Teacher epistemology and scientific inquiry in computerised classroom environments.*Journal of Research in Science Teaching*,, **32,** 839-854.

Newmann, F. M. (1990). Higher order thinking in teaching social studies: A rationale for the assessment of classroom thoughtfulness, *Journal of curriculum studies, 22*(1), 41-56.

Resnick, L. B. & D. P. (1992). Assessing the thinking curriculum: New tools for educational reform, In B. R. Gifford & M. C. O'Connor, (Eds)., *Changing assessments: Alternative views of aptitude, achievement and instruction,* Klewer Academic Publishers: Boston.

Tobin, K. G. (Ed.) (1993). *The practice of constructivism in science education,* AAAS Publications, Washington, DC.

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