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Tracks for learning: Metacognition and learning technologies

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Research into metacognition suggests that learners need to become aware of the processes of their learning as distinct from the content of learning to improve their learning outcomes. Information technologists have the opportunity to take theoretical views of learning and develop design models to investigate and demonstrate these theoretical views. One way of doing this is by providing interactive multimedia programs that support student centred learning.

> "There are too many examples of educational multimedia that fail to exploit its capability to offer interactive practice of a subject" (Laurillard, 1993).

This paper outlines an investigation into the nature of metacognition and its relation to the learning process in a constructivist interactive multimedia learning environment.

Learning is an intriguing process for students, teachers and designers of educational software The learning and teaching process may now be one that is combined and integrated into interactive multimedia programs to support the construction of meaning by the learner. Computers provide students with access to information and knowledge reconstruction that is presented in multiple media. A review by Jonassen (1996) further supports this view where he proposes that "multimodal access is essential when teaching today's video generation". Students now have the opportunity to take advantage of learning by using interactive multimedia programs in order to develop problem solving techniques.

One way of supporting the students learning processes and encouraging problem solving skills is through the provision of metacognitive support for the writing process that can be used by learners whilst solving problems within an information landscape. An example of this metacognitive support in the form of genre templates has been embedded in an interactive multimedia program. The package described gives students an opportunity to gather, organise and illustrate their ideas

dependent on a set task. Within the interactive multimedia program the metacognitive support template is unique in that it aids students in their thinking, information processing and monitoring of their own learning processes. Earlier interactive multimedia programs promoted learning environments where students mirrored accepted views. In addition this version facilitates an environment where learners interpret their own views of reality by understanding how they arrived at these interpretations and views. It provides support in the form of new schemata in the process of accommodating mental models.

This paper will briefly outline the definitions associated with and the relationships between metacognition and learning technologies. It will also consider how this relationship effects the learner, teacher and future designers of interactive multimedia programs.

Metacognition

Metacognition has been defined as an "awareness of one's own cognitive processes rather than the content of those processes together with the use of that self awareness in controlling and improving cognitive processes" (Biggs & Moore, p 527, 1993). Other researchers have referred to metacognition as "cognitive strategies", (Paris and Winograd, 1990) "knowledge about executive control systems" (Brown, Harper and Hedberg, 1994), "monitoring of cognitive processes" (Flavell, 1976), "resources and self regulating learning" (Osman and Hannafin, 1992) and "evaluating cognitive states such as self appraisal and self management" (Brown, 1996). These are broad terms that are all equally important depending on the characteristics of the learner and their approach to learning. If we look at learners who are aware of their metacognitive processes they will more than likely be people who possess "self determination or autonomy in learning and problem solving. They will be able to refer to the what, how, when, where and why of learning when carrying out complex cognitive activities.

These will be the learners who do this by:

- *planning*, deciding what their goals are and what
- *strategies* to use to get there; decide what further
- *knowledge* or resources they need;
- *monitoring* progress along the way; am I going in the right direction;
- *evaluating* when I have arrived; and
- *terminating* when the goals have been met (Biggs and Moore, p307, 1993).

A review of Houssman's (1991) research further supports this notion. On investigating metacognitive processes through student self reporting journals she found that students who were aware of their metacognitive processes and monitored their own learning processes became more proficient learners in a computer class as compared to those who did not

monitor their metacognitive processes. Metacognition for the purpose of this review is defined as self awareness of one's own cognitive processes.

Learning technologies

In order to define learning technologies one needs to look at the relationship between human learning and those systems techniques and equipment which address this fundamentally human attribute. Rieber (1991) has examined this relationship in his work on instructional technology examines learning from a constructivist perspective based upon the work of Piaget's theory of cognitive development.

> Learning can be viewed not so much as the acquisition of knowledge but as the constant reconstruction of what is already known. Individuals do not simply add information to their knowledge banks. They either revise existing mental structures to accept new information or formulate new structures based on old ones when an existing structure is no longer sufficient. Engaging new ideas to prior knowledge in a never ending pattern of going from the known to the unknown. Learning within a microworld relies on the natural tendency of a learner to seek equilibrium. Successful microworlds encourage learning conflicts to arise in order to activate the process of equilibration. It is only through the resolution of these conflicts that learning can take place (Rieber, 1991).

The computer as a microworld by engaging the learner, acts as an interactive medium and allows for the development of the learners personal knowledge acquisition and representation by amplifying their thinking skills.

"Learning technologies represent any environment or definable set of activities that engage learners in knowledge construction and meaning making" (Jonassen, 1995). Interactive multimedia programs can be used as a means to support student learning and knowledge structures. In line with the philosophy of children constructing their own learning through interaction with experiences in which they "struggle" to find equilibrium between their current level of understanding and that of the next, it could be argued that it is not the computer that should provide the knowledge structure for the learning process and guide the student through a program, it is the student. Students should develop their own understanding of the structure of the information. This does not mean a simple pass throughout the information base. What it does mean is placing students in an environment that supports the way in which they can construct their own understanding of a particular knowledge base or piece of information.

What a powerful computer software environment provides is the tool for "empowering" students to engage in a cognitive struggle with new learning situations, allowing them to take control of their own learning, reflecting on their thinking and on the consequences of choices they make

all of which are factors in developing metacognition (Sewell, 1990). Additionally, it can provide a context for learning and the opportunity to observe "expert" models of particular skills. The author is of the opinion that computer software environments should be used as facilitators of thinking and knowledge construction so that students can devise their own ways of handling the information that is presented in multiple modes of representation.

What is the relationship between metacognition and learning technologies?

Learners need to know how to monitor and regulate their own learning processes when solving problems within an interactive multimedia learning context. The author believes that metacognition helps learners exhibit cognitive processes that analyse and manage their own thinking in pursuit of knowledge acquisition in order to solve problems, gain insight and become critical thinkers. An example of a metacognitive tool is a genre template. Metacognitive tools in the form of genre templates for writing can provide further support for the process of learning. In an interactive multimedia student centred learning environment genre templates help remind students of planning, monitoring and regulating their own learning. If students know how to monitor their cognitive processes and regulate their learning to solve problems they will then be better able to select appropriate metacognitive strategies to facilitate their own problem solving skills. Problem based learning and interactive multimedia can support students by encouraging metacognitive learning and problem solving skills.

Instructional technology provides us with both metacognitive support tools and cognitive tools that are based upon a constructivist epistemology. Constructivism is concerned with the process of how we construct meaning and knowledge in the world as well as with the results of the constructive process. How we construct knowledge depends upon what we already know, our previous experiences, how we have organised those experiences into knowledge structures such as schema, mental models, and the beliefs that we as individuals use to interpret our own realities of the objects and events we encounter within the world.

Norman (1983) argues that

> computers support reflective thinking when they enable users to compose new knowledge by adding new representations, modifying old ones and comparing the two.

Cognitive tools should be readily accessible to learners to support reflective thinking on what they have learnt and how they came to know it, supporting internal negotiation of meaning making and constructing personal representations of meaning making within the context of

learning. "Cognitive tools provide an environment and vehicle that often requires learners to think harder about the subject matter domain being studied while generating thoughts that would be difficult without the tool" (Jonassen, 1996). Jonassen views technology as a tool for accessing information, representing ideas, communicating with others and generating products.

An example of the relation between metacognition and learning technologies

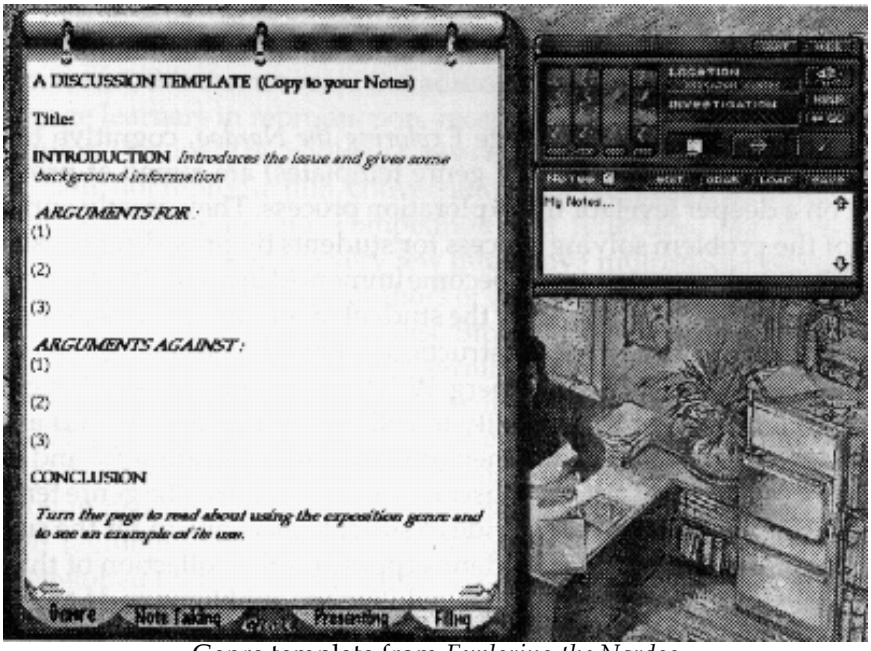
Exploring the Nardoo is an example of an interactive multimedia program which provides a range of cognitive tools in an information landscape to support student investigations, reflections and thinking processes. Simulations and support tools which allow: multimedia reporting are embedded in the package and are supported by several metacognitive tools for the writing process. These tools not only include details about genre but also scaffolding templates to support the learners (Harper, Hedberg, Wright and Corderoy, 1996) in constructing their own realities using the constructs and processes in the environment on a new content domain.

The templates provide a cognitive support for problem solving by establishing a frame work for student presentation which will concentrate thought, facilitate investigation and the development of critical and creative thinking. It incorporates problems that challenge students to become active participants in the learning process. The Nardoo provides the student with a flexible set of tools, made available through a personal digital assistant, for the investigation process. This package also enables the user to record thoughts and impressions "on the fly" whilst examining media stories. It has the potential to help students reorganise or revise their thoughts to better make sense of what they see and hear. Students are able to document their emerging ideas in support of an investigation or problem solving exercise whilst viewing different media. One way of organising thoughts that are presented as information represented in multiple media is by using a template.

By making such templates available and encouraging their use, we are assisting students through a modelled form of outlining. Identifying concepts within their notes that bear some relationship to part of a template structure requires high order thinking skills which "a) causes focusing on important points, b) helps students gain familiarity with text structure, c) aids retention, d) generates useful alternative texts to supplement materials read, and e) causes active participation in learning" (Biancol and McCormick, 1989 in Schroeder & Kenny, 1994, p966). "The value of this modelling process is not faculty, learning style, level of school, or type of writing dependent" (Harper, Hedberg, Bickell, Wright and Corderoy, 1996). It is to help students match their learning processes with that of a genre template. While at the same time organising

information and the reconstruction of new knowledge at a time appropriate to the student.

Students need to cultivate and develop their own understandings and interpretations. Of significant importance in this package is the development of a "new genre" born of computers and their associated technologies the multimedia genre, which is a melding of all communications, written, oral visual and aural. How students monitor, regulate and control not only their cognitive processes, but the information and knowledge structures they wish to present, which is represented in multiple media, will be of great assistance to teachers and instructional designers.



Genre template from *Exploring the Nardoo*

Who is this for

What research in this area is not showing is how metacognition, as a support tool for the writing process, can be manipulated and extended by students for themselves in an interactive multimedia program. To further enhance meaningful learning within these programs researchers need to look at how learners use metacognitive support, in the form of genre templates, as processes, strategies and skills, in organising the presentation of reconstructed knowledge and information that is put forward in multiple modes of media for representation during the formulation of a solution to a problem.

More research is needed is this area to help designers provide learning environments that give learners access to metacognitive support. Rather than developing ever more powerful teaching hardware, researchers should be concentrating on how to help learners think more effectively. According to Jonassen (1992) we should focus less on developing sophisticated multi media delivery technologies and more on thinking technologies, those that engage thinking processes in the mind Recent research by Jonassen and Lehrer indicates that "learners develop critical thinking skills as authors, designers and constructors of knowledge and learn more in the process than they do as the recipients of knowledge prepackaged in educational communications" (Jonassen, 1996). Learners, teachers and instructional designers must all work towards the same goal of creating a richer student centred environment that develops learners metacognitive abilities and problem solving skills.

Learners perspective

In relation to the software package *Exploring the Nardoo*, cognitive tools (a simulator, presentation guide and genre templates) are aimed at providing support on a deeper level for the exploration process. They greatly enrich the quality of the problem solving process for students by providing the student with unhindered access to act and become immersed in a real situated process. They also promote the adoption by the student of the active learner mode and in so doing support the active construction of knowledge during the process of solving a problem (Harper, Hedberg, Wright and Corderoy, 1996). A necessary skill in problem solving is the ability to collect and manipulate and analyse many different forms of data and then present them in meaningful and useful ways to any of the many different discourse communities. The genre template tool in the presentation guide provides a suitable mechanism for the support and development of this skill. Student support for the collection of this data through note taking and the resultant solutions to problems need to include modelling of various styles of discourse used in different communities.

From a learners perspective, using the genre templates should encourage qualities of meaningful learning. Meaningful learning includes: "active, constructive, collaborative, intentional, conversational, contextualised and reflective learning" (Jonassen, 1995) together with an awareness of this process. The use of genre templates helps learners choose strategies in planning, monitoring and regulating implied learning by identifying the relationship between their work and the appropriate genre. Students can devise their own ways of learning or solving problems and in doing so can be at times engaging in active, construction, collaboration intentional, conversational, contextualised and reflective learning by using interactive multimedia programs. Jonassen and Reeves (1996) through their ongoing research into learning technologies and the use of authoring environments

as cognitive tools, found that students needed to develop major thinking skills to use as designers of learning (Carver, Lehrer, Connell and Erickson, 1992). The author wishes to consider that if students are not aware of how to learn they now have the chance to further sharpen their metacognitive strategies and abilities by using the metacognitive tools provided as support in interactive multimedia information landscapes. Alternatively, if they are aware of their metacognitive processes when using interactive multimedia they will be able to understand the relevance of metacognitive support and perhaps start to use a combination of these support tools in ways not yet discovered by teachers and instructional designers. Other questions will include whether or not the implementation of this support is dependent on learners approach to learning, motivation and cognitive style.

In contrast, this cannot occur in traditional education institutions because they engage learners in reproduction, reception, repetition, competition and prescription. The use of technology however, supports learners in knowledge construction; not reproduction, conversation; not reception, articulation;, not repetition, collaboration; not competition and reflection; not prescription (Jonassen, 1995). At this stage very few interactive multimedia programs are designed to support learners as authors or designers of their own knowledge reconstruction and learning processes. Brown (1996) agrees with the use of technology to support processes of learning and recommends that "future research is needed in this area. The learning process and the end product should all have equal importance for the development of deep, self regulated learning." Interactive multimedia programs can support students during the construction process and in turn can provide a wonderful cognitive tool for deep self regulated learning. Yet interactive multimedia programs are still being developed that support and encourage surface approaches to learning.

Designers perspective

Too many software programs are being produced that place the learner in active control of processes and interaction but are still only a kind of metacognitive drill and practice (Stern, 1992, p230) via information data bases. This practice overlooks a basic point that learning is fundamentally an edition process and that it is not skills that improve but ideas that change. Learning is not a mechanism learnt through repetitive practice but referred previously by Jonassen as conversation, articulation, intellectual partnering, knowledge construction, collaboration and reflection and as Reiber suggests a resolution to conflict resulting from disequilibrium. Designers need to be aware of the metacognitive processes that learners incorporate into their own learning so as to better design interactive multimedia programs that support how learners cognitively process and organise information in problem based and student centred learning.

Teachers perspective

According to constructivism, the teachers cannot map their own interpretations of the world onto the learner because they do not share a set of common experiences and interpretations. Reality (or at least what we know and understand of it) resides in the mind of each knower who interprets the external world according to his or her own experiences, beliefs and knowledge. When using multimedia/hypermedia environments as a resource for cognitive processing and problem solving, Idol, Jones and Mayer (p80, 1991) provide us with research that is in the hallmark of successful models of teaching to emphasise thinking skills. These include modelling, coaching, inquiry, articulation, reflection and exploration all of which can be found in *Exploring the Nardoo* in the form of support for knowledge construction in the formulation of interpreting a solution to a problem. The genre templates support this notion of providing strategies that will help students encode and manipulate the information they encounter. This helps students develop further information and note taking skills. Teachers can at any given point, guide students through this process, as the students own realities unfold.

A teacher now has to adapt to the role of being a knowledge transmitter in a bid to create students who are flexible, motivated problem solvers. *Exploring the Nardoo* offers teachers the opportunity to individualise instruction, place learners in open-ended student centred investigation and shift from their traditional instructor role to that of mentor and co learner (Harper, Hedberg, Wright and Corderoy 1996). The computer and the students use of metacognitive support tools has the potential to change not only what teachers teach in terms of subject matter or content but how they teach in terms of process.

Conclusion

Several factors need to be addressed in the relationship between metacognition and learning technologies. Learners need to be made aware of how they learn, by monitoring and gaining control of their cognitive processes. One way of doing this is through interactive multimedia programs with embedded metacognitive support tools for processes such as writing, that promote problem solving skills for the organisation of information presented in multiple media for representation. This will enable an increased understanding of how students interact with the genre templates as a means of support for the writing process during the learning process, required both for the teacher, instructional designer. Lastly the author feels that systemic change can occur through continued research, the integration and implementation of well designed interactive multimedia programs based upon theoretical approaches to constructivism.

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