THE INFLUENCE OF REFLECTIVE TOOLS ON TEACHING STRATEGIES AND SUBJECT DESIGN

Dr Brian Ferry and Dr Christine Brown

Faculty of Education, University of Wollongong, Australia.
email: Brian_Ferry@uow.edu.au
email: Christine_Brown@uow.edu.au

ABSTRACT

This paper discusses the impact of student use of electronic thinking tools on teaching and learning strategies, depth of student reflection, staffing requirements and technological fluency of staff and students in a fourth year subject for pre-service primary teachers focusing on technology education. The theoretical underpinning of this subject is firmly based in a constructivist approach to learning, and employs a mindtool (Jonassen, 1996) to support deep student reflection and sharing of the design, make and appraise process.

The construction of a process journal is an important aid to student reflection and self-analysis of recent learning experiences. Use of multimedia construction tools to enhance the journal writing process has evolved in the Design, Make and Appraise elective over a period of six years. The physical nature and pedagogical impact of the journal have changed due to the development of simple yet sophisticated multimedia construction tools. The change from script dependent HyperCard® to user friendly HyperStudio® has permitted a shift in multimedia production responsibility from a computer literate lecturer to computer novice students as peer buddies, and most recently to technologically fluent students working collaboratively.

This shift has been accompanied by an apparent reduction in staffing requirements, yet more creative records of student learning. As more classes have experienced multimedia journal construction, a larger pool of past student work has been available to assist subsequent students to frame the scope and nature of the task. More recent journals show a greater degree of sophistication and more accurately reflect the preservice teachers' experiences with the design, make and appraise processes.

Ongoing subject design can be significantly influenced by the nature of available thinking tools. As the tools become easier to use and more sophisticated, lecturers need to familiarize themselves with the relevant pedagogy, and upgrade their teaching and learning strategies to maximize the benefits of developing technology. The Design, Make and Appraise elective is presented here as a case study to support these claims. The apparent decrease in staffing requirements has been offset by the development of HyperStudio skills in other subjects. This repeat exposure to a mindtool not only improves student computer literacy, but has a potentiating effect on the nature of the tasks and depth of information processing lecturers can set and expect. Improved computer literacy leads to increased peer tutoring, more self-regulated learning, and decreased student reliance on staff.

KEY WORDS

Cognitive tools, reflection, multimedia journal, design.

1. INTRODUCTION

Constructivist learning theory tells us that learning is a very active and social process, which requires considerable effort on the part of the learner to integrate new knowledge into existing schema. Such learning involves more than the accumulation of facts as it also encompasses knowledge of the *process* of learning which is considered to be important at the meta level: spanning a cyclical process of planning, monitoring and reflection (Lederman & Latz, 1995). However, this metacognitive knowledge can be difficult to structure and represent, and may require considerable reflection on what was experienced and what was learned. We argue that it is this process level of understanding that allows learners to flexibly transfer experience from one situation to another.

In the design and make process, students develop metacognitive knowledge through repeated exposure to and reflection upon case-based experiences. These usually vary in content and purpose and repetition allows students to separate common elements of process from case specific details.

When pre-service teachers are experiencing such a process they have three levels of understanding to develop. First, they need to understand the scientific principles that underpin their design and make project. Second, they need to understand the design and make process through repeated experience, and third, they need to use their reflections on the design and make process to inform their planning of supportive environments for students engaged in design and make. When a constructivist setting is used to facilitate this process, then they are likely to discover personal misconceptions that need to be addressed through extensive and intensive interaction with peers and tutors. It is through this process that they generate new understandings about their role as a teacher and a learner in the design and make process.

It is not surprising that these three levels of understanding create a high cognitive load. In the field of technology overall developments have generated high cognitive loads associated with a ‘knowledge explosion’ which has been difficult to manage, yet specific aspects of technology offer us new ways to manage these loads. For example, computer based thinking tools help learners to visualize and manipulate external representations of knowledge structures and this can foster discussion and facilitate communication and negotiation of meaning (Jonassen & Reeves, 1996). Electronic information storage and representation permit rapid editing and recombination of material in the most appropriate medium. In the past many scientific papers were limited to a text-only description of methodology and this frequently prevented others from reproducing results, as key contextual factors vital to the results were not recognized and described. Visual or audiovisual recording of methodology may have enabled others to subsequently identify significant variables and to better understand the context.

This paper examines the impact of the use of computer-based multimedia thinking tools on the educational needs of preservice teachers involved in a fourth year design, make and appraise subject. It describes the evolving nature of this subject run by the authors (individually or in tandem) for pre-service Primary teachers over a six year period. The focus of this fourth year *second* session elective is the design and make process – an important element of technology education, which is anchored in the NSW curriculum in the key learning area of science. However, subjects don’t run in isolation. For the last three years, one of the authors has refined a *first* session fourth year elective which explores the use of information technology to support constructivist learning environments and considerable synergy has resulted from the sequence and juxtaposition of these two electives. We feel that there has been a continuous dialectic among the lecturers and students involved in these subjects and that this has occurred in the context of rapid technological evolution.

2. THE DESIGN MAKE AND APPRAISE ELECTIVE

2.1 THEORETICAL BASIS FOR MULTIMEDIA CONSTRUCTION

A constructivist approach to learning is based upon the supposition that as learners interact with the world, they construct their own experience and knowledge (Lyddon & McLaughlin, 1992; Novak, 1988). Therefore, learning is viewed as "the product of self-organization" (von Glasersfeld, 1989, p.136). This learning process is supported by two broad principles: first, knowledge is not passively received but actively constructed by the learner, and second, learners generate understanding when they relate prior knowledge to present experiences (Wheatley, 1991).

Often this occurs when a learner attempts to reconcile differences that exist between his/her explanation and the explanations of others about the same phenomena (Osborne & Wittrock, 1985; Posner et al., 1982). Such a process frequently involves intensive and extensive interpersonal negotiation (Osborne & Wittrock, 1985; von Glasersfeld, 1989), which highlights the importance of the social dimension of constructivism.

Collins (1990) contended that the following strategies could support learners and instructors who adopted a constructivist approach to learning. Each involved a shift:

- from whole-class to small-group instruction;
- from lecture and recitation to facilitation and coaching;
- from working with better students to working with all students;
- from a competitive to a social structure;
- from verbal thinking to the integration of visual and verbal thinking;
- from all learners learning the same things to different students learning different things;
- towards more engaged students doing assessments;
- towards an assessment based on products, progress, and effort;

The authors have adopted these strategies in the subjects they teach and believe that this has encouraged preservice teachers to create a learning environment in which their students *are able to* adopt constructivist learning processes. However, we also believe that these strategies don't emphasize the vital process of deep reflection which Hoban (1996) argues is essential if preservice teachers are to develop a satisfactory understanding of their role and the role of the student in constructivist based learning. Furthermore, it takes time and effort to develop reflection skills. Reflection requires retracing and analyzing a process which you have experienced. Others may challenge your interpretations, and this can be emotionally threatening (Ramsden, 1990). Social and emotional support can be offered via respect for discussion, humor and trial and error tactics; while concrete support can be offered via cognitive tools.

Jonassen (1991) describes cognitive tools as computer-based devices that support, guide and extend the thinking processes of the users and engage them in meaningful processing of information. Cognitive tools that function as *mindtools* (Jonassen, 1996) are those that engage the learner in higher order thinking skills such as critical, creative and complex thinking. An example of a mindtool is a computer-based concept mapping tool that learners use for knowledge construction. During the process of knowledge construction learners may employ critical thinking skills to evaluate, analyse and connect concepts and information; creative thinking skills to elaborate, synthesise and visually arrange concepts and information; and complex thinking skills to assess, revise, find alternative structures and make choices.

When students construct a multimedia *journal,* they use the computer as a cognitive tool (even at the most rudimentary level of production). The journal may be used to simply record a series of events in a range of media formats or its use may be extended through the process of knowledge construction where learners employ critical thinking skills to evaluate, analyze and connect concepts and information. They may also use creative thinking skills to elaborate, synthesize and visually arrange concepts and information. When students use their journal this manner they can retrace steps, and use complex thinking skills to assess, revise, find alternative structures and suggest improvements.

This is not where the journal writing task began for students in the Design, Make and Appraise elective – it is where it is currently positioned and the following account traces the evolution of this student task.

2.2 TASK EVOLUTION OVER SIX YEARS

Technology education in primary schools should be developed through integrated, interdisciplinary investigational topic work (Australian Academy of Science,1991). Preservice teachers need to have first-hand experience with the processes that their pupils will experience in order to support them. It follows that a technology subject that introduces preservice teachers to the strands of technology education should use this approach, and empower trainee teachers in the design and make process (Bonollo, 1993). To this end, lectures and tutorials were scheduled to support the students' first experience of the stages in the technology/design process. Students were learning about the process in parallel with their first experience of it.

Table 1 presents a summary of the key student tasks relevant to this discussion in two fourth year electives – information technology in education and the design and make process in science. Only the latter has run for six years.

Table 1

Key Student Tasks Across Two Fourth Year Electives

	Session 1 – IT elective	**Session 2 – Design, Make and Appraise Elective**			
Year		**Multimedia Producer**	**Software Tool**	**Design Tasks**	**Journal**
1993	Not offered	Lecturer	HyperCard® both concrete*	2 tasks,	Personal, hand written
1994	Not offered	Nil	CD-ROM from 1993 Design Projects	2 tasks, both concrete*	Personal, hand written
1995	Not offered	Nil	CD-ROM from 1993 Design Projects	2 tasks, both concrete*	Personal, hand written
1996	Web site (PageMill); Stack (H/S 3.0)	Student	HyperStudio 3.0 (H/S 3.0)	2 tasks: 1 concrete* and 1 electronic	Personal, hand written; and electronic journal of partner
1997	Web site (HomePage); Stack (H/S 3.1)	Student	HyperStudio 3.1 (H/S 3.1)	2 tasks: 1 concrete* and 1 electronic	Personal electronic, with presentation of teaching strategies
1998	Web site (HomePage); (H/S 3.1)	Student	HyperStudio 3.1 (H/S 3.1)	2 tasks: both can be electronic	Personal electronic

* Technology education is much broader than computer use, hence the main focus of the design process in the earlier years was on student exploration of a problem which required them to construct a concrete solution. Examples include the design of an electric circuit to power bicycle lights, a fishing rod to catch black fish, a portable dog kennel for travel, and an underwater housing for a video camera. Students were required to identify a problem which was relevant to them, conduct a needs assessment, then design and prototype a solution.

The information technology elective, run since 1996 in session one of the fourth year course, provides students with the opportunity to construct a web site using a simple web authoring tool like Claris HomePage and a multimedia project shell using HyperStudio. This skill development in the use of information technology tools to construct meaning has had a significant bearing on the design and make tasks that could be set the following semester.

3. THE INFORMATION TECHNOLOGY ELECTIVE – A CATALYST FOR CHANGE

In 1996, this elective was created to meet the growing demand for increased pre-service teacher skill in information technology. Four main tasks that students were to achieve emphasised creativity, skills, theory and problem solving. These evolved as shown in Table 2.

Table 2

Task Evolution in Edit 407

Tasks/Student Number	**1996**	**1997**	**1998**
T1: Web Site (creativity-individual work)	PageMill site–open ended student prod'n	HomePage site–more constrained prod'n	HomePage site–skill dev't then free prod'n
T2: HyperStudio task (skills–work in pairs)	Students created an empty shell for others to fill	Students created an empty shell for others to fill	Students created an empty shell for others to fill
T3: Essay (theory–individual work)	Creative use of computers and technology in the class	Constructivist theory, practicalities and evaluation	Constructivist theory, practicalities and evaluation
T4: Resources (problem solving–individual work)	Image, text and audio collection on a theme	Web sites, documentation for H/S and image collection	Portfolio presenting H/S stack and web site, but emphasizing stratgies for use
Student Numbers	14 (single class)	18 (single class)	40 (two classes)

The general trends displayed in the table can be summarized as follows:

- web and multimedia construction tools became simpler to use each year;
- there was a shift in focus from skill development with the tools to teaching and learning strategies using the tools;
- a variety of strategies were used to maintain individual and group task balance in the face of escalating student numbers;
- lecturer proficiency with class management strategies in a technology rich environment increased.

From 1996 to the present, proportionally more students with production skills in HyperStudio have taken the design and make elective in session two. Not only have their HyperStudio skills become more sophisticated, but also students have exhibited more general proficiency and confidence with information technology. To capitalize on this, the authors have made annual changes to the design and make tasks, as shown in Table 3.

Table 3

Evolving use of Hyperstudio in the Design and Make Elective

Feature	1996	1997	1998
HyperStudio related Task Description	Complete a multimedia journal of the Design and Make (D&M) process of a partner. You will need to monitor the work of a partner, question them and discuss strategies.	The journal should be in HyperStudio form. It should contain plans and comments about trials and prototypes, plus a description of your final project, an appraisal and a suggested teaching sequence.	As per 1997 plus progress (WIP) presentation
Pattern of work load	D&M task with concurrent personal journal & a peer support partner, followed by multimedia journal of partner's design.	D&M task with concurrent HyperStudio journal.	D&M task with Concurrent H/S journal. WIP Presentation at any stage.
Time for completion of HyperStudio work	6 weeks	14 weeks	14 weeks
Social Focus of HyperStudio Task	Peer experiencing the design process	Individual experiencing the D&M process	Individual experiencing the D&M process; WIP presentations.
Nature of Reflection associated with HyperStudio use	Experiences of another – awareness of the process support and recording	Experiences of self-awareness of the process, via recording, reflection and analysis	Experiences of self-awareness of the process, via recording, reflection and analysis; awareness of others through WIP presentations
Personal journal with format	paper based, with non-computer based design task	HyperStudio, with non-computer (17) or computer (2) based design	HyperStudio, non-computer (21) or computer (1) based design
Concurrent load while working on HyperStudio	Essay	Essay; Design and make task	Essay; Design and make task
Students with prior HyperStudio experience	7/20 (simple HS task)	8/19 (more complex HS task)	14/22 (H/S similar to 1997)
Class Environment	Science lab then access to IMM lab for 1 hour per week	IMM Lab for the entire class	IMM Lab for the entire class

The length of time for production and complexity of content have increased and this has created a higher concurrent workload, but more technical support is now available through a highly skilled peer support network. This is complemented by increased access to the computer laboratory (outside class time and in other classes) and access to technical support staff.

4. TRENDS EMERGING ACROSS SUBJECTS

The willingness of the authors to collaborate on task design, to share student support, and to present a similar teaching 'philosophy' has enabled growth in the following strands:

- *Teaching and learning strategies* – It has been important to capitalize on improved student production skills. Many teaching and learning strategies have undergone annual adjustments. These includes strategies for task presentation (more use of audiovisual material), student use of facilities (increased student access to computer facilities), student access to past work (via browsing of previous student work on CD-ROM), organization of peer support (skill mentoring system), work presentation (usually in multimedia format) and archiving (systematic storage of student projects by staff). All these strategies reflect increased staff and student proficiency and comfort with the use of information technology tools to communicate experience and understanding.
- *Depth of student reflection* – The initial electronic journal constructed in 1993 in HyperCard® was a whole class journal authored by one of the lecturers. It contained student entries gathered throughout the session – student photographs and audio files from interviews, scanned sketches and photographs of various stages of prototype development, and selected entries from the reflective journals. This class journal proved to be popular and 88% of preservice teachers used it on more than one occasion for its reference and motivational value. However, it was a class reflective tool, rather than a tool for in-depth individual student reflection. When students first applied HyperStudio skills to the design elective in 1996, they were asked to observe and record in multimedia format the design and make process of a peer buddy. This request was made to separate the cognitive load of multimedia construction from the design and make process. It was hoped student focus on the design experience of a peer buddy would heighten their own process awareness when the time came to tackle a design task and maintain a written journal. The computer was not a major focus of the subject, hence student access to the computer laboratory was limited. By 1997 the design elective was run in the interactive multimedia laboratory. Students were much more fluent with HyperStudio, especially those who were concurrently enrolled in a further information technology elective which required more advanced HyperStudio techniques. The authors were therefore happy to request that students build their design and make journal in HyperStudio. This enabled them to creatively capture the key stages in their *own* production in the most appropriate medium.
- *Flexible staffing requirements* – It has become apparent to the authors that all staff *don't* need to be highly proficient in all construction tools. If students gain the basic skills in one subject, these can be extended in others with more general technical support for the construction process, and the peculiarities of specific hardware and software. What staff do need to take into account is the adjustments they must make to their task design as student fluency with knowledge construction tools increases. Content experts should partner where possible with technologically fluent process experts. As students become highly skilled with multimedia construction through repeated use across a range of subjects, *they* will provide a logical source of tutors for more junior years, and should be encouraged to complete projects with staff as content advisors. This arrangement would be mutually beneficial.
- *Technological Fluency* – While this is a likely end point given considerable time, collaborative ventures among staff can speed up the process and help to reduce the stress of change. Teaching and learning strategies should be shared, and tasks designed to flow through a sequence of subjects. We believe that lecturers should no longer be

constructing any subject in isolation. Electronic storage and centralized access to resources (such as provided via the World Wide Web) allow multiple lecturers to reference standard skill support material.

5. CONCLUSIONS

Over the past six years we have been fortunate to be involved in subjects that have been influenced by the enormous technological changes that have been occurring in education. This has challenged us to continually update the way we present our subjects so that we can take advantage of what the new technologies have to offer our students. One of the key factors that has contributed to the success of our subjects has been the continual dialogue between the lecturers involved. Each has contributed to the success of the subjects in different ways and we feel that this is an important factor to recognize.

Our shared experiences with the design and make elective have shown that:

- Ongoing subject design is influenced by the nature of the thinking tools available.
- As the electronic tools become easier to use and more sophisticated, lecturers need to upgrade the teaching and learning strategies associated with their use in order to maximize the benefits of the developing technology.
- The level of student computer literacy is increasing through the broad adoption of thinking tools and this has a potentiating effect on what tasks lecturers can set and what levels of achievement they can expect.
- The overall cognitive load on the student and lecturer need to be kept in check. At times the decisions taken have involved a certain amount of soul searching and animated discussion among the lecturers and the students, but we have maintained our sense of humour as well as our sense of adventure.

However the story is not complete and we expect to continue to be challenged to exploit advances in technology for the benefit of the preservice teachers in our classes and the pupils that they will ultimately teach.

6. BIBLIOGRAPHY

Australian Academy of Science. (1991). *First steps in science and technology.*. Canberra: Australian Academy of Science.

Bonollo, E. (1993). *Designing courses in industrial design.* Unpublished PhD. Thesis, University of Wollongong. Australia

Collins, A. (1990). The Role of Computer Technology in Restructuring Schools. In Sheingold, K. and Tucker, M. S. (Eds),*Restructuring for Learning with Technology*. (pp. 29-48). New York: Center for Educational Technology

Hoban, G. (1996). *Professional development based upon interrelated principles of teacher development.* Unpublished PhD Thesis. University of British Columbia.

Jonassen, D. H. (1991). What are cognitive tools? In M. Kommers, D. H. Jonassen, & J. T. Mayes, (Eds.) *Cognitive tools for learning computers and system sciences*, (Vol. 81). Berlin: Springer-Verland in cooperation with NATO

Jonassen, D. H. (1996). *Computers in the classroom: mindtools for critical thinking.* New Jersey: Merrill.

Jonassen, D. H., & Reeves, T. C. (1996). Learning with technology: Using computers as cognitive tools. In D. H. Jonnassen (Ed.) *Handbook of Research on Educational Technology*. New York: Scholastic Press in collaboration with the Association for Educational Communications and Technology.

Lederman, N. G. & Latz, M. S. (1995). Knowledge structures in the preservice teacher: Sources, development, interactions, and relationships to teaching. *Journal of Science Teacher Education*, 6(1), 1-19.

Lyddon, W. J., & McLaughlin, J. T. (1992). Constructivist psychology: a heuristic framework. *Journal of Mind and Behaviour*. 13(1), 89-107.

Novak, J. D. (1988). Learning science and the science of learning. *Studies in Science Education*. 15, 77-101.

Osborne, R., &Wittrock, M. (1985). The generative learning model and its implications for science education. *Studies in Science Education*.. 12, 59-87.

Posner, G. L., Strike, K. A. Hewson, P. W. & Gertzog, W. A. (1982). Accommodation of a scientific conception: Toward a theory of conceptual change. *Science Education*. 66(2), 211-227.

Ramsden, P. (1990). *Learning to Teach in Higher Education,* London: Routledge.

von Glasersfeld, E. (1989). Cognition, construction of knowledge and teaching. *Synthese*. 80 : 121-140.

Wheatley, G. H. (1991). Constructivist perspectives on science and mathematics learning. *Science Education.* 75 (1), 9-21.