La Trobe University, Bendigo

Learning in School through New Technologies

by Vaughan Prain

Worner Research Lecture 1999

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Biography

Associate Professor Vaughan Prain is a graduate of the University of Melbourne and Monash University, and is current director of the Research Centre for Rural Education, La Trobe University, Bendigo. His research interests include literacy education and evaluation, the theory and practice of teaching writing, the use of computers in learning, and critical literacy. He is a member of the international research group, Models in Science and Technology Research in Education, and was a Visiting Fellow to the University of Reading in 1995. He has a particular research interest in the use of writing for learning in science, a field in which he has published nationally and internationally.

Learning in School through New Technologies

Vaughan Prain

'Media are not responsible for learning; learners are.'
Jonassen, Campbell & Davidson, 1994

Introduction

This evening's lecture is the fifth in the series, and tackles a topical issue in education, namely the role of new technologies, such as computers, the Internet and electronic software programs, in promoting effective teaching and learning. Governments throughout the world are putting their faith in new technologies as a way to make learning in schools supposedly more efficient and relevant to the future, and new practices are emerging. However, because we are in the middle of these changes many questions remain unanswered. For example, how should we conceptualise the relation between technologies and learning? Are they simply to be seen as better vehicles in which we travel faster to learn more quickly? Are they, as Draper (1992: 170) suggested, new 'gloves' that fit human abilities 'more intimately' than the coarse tools or resources of the past?

There are also questions about the use of particular technologies, and their implications for students and teachers. For example, is the Web, as advocates claim, a vast inexpensive superlibrary and communication system, what Papert (1994) has named the necessary way for schools to link to the next century, or is it merely a badly organised, information-choked maze? Clearly it is both and more. We also need to ask what changes are required of teachers' and students' beliefs and practices, and of school organisation, if technology-enhanced environments are to serve learning. Then there are challenges for researchers in seeking to explain the causes and effects of these new practices. As we know, it is so much easier to research outcomes you can comfortably foresee, but commentators such as Papert (1980) and others insist that these changes require new and demanding reconceptual-isations of the nature of cognition and learning. At the very least, we need current research-based evidence to justify and guide these new learning environments. This evening's presentation cannot answer all these questions, but will provide some emerging answers, especially on the question of how these new technologies relate to learning.

To frame discussion some current concerns about, and claims for, new technologies in learning in schools will be reviewed. Then the issue of effective research on teaching and learning generally, especially in the context of university research, will be considered. This is the question of what kind of university research into teaching and learning best serves schools. In this regard we are strongly committed to the development of longterm collaborative research partnerships with schools as one important way to address the Faculty's regional research mission, and I will outline briefly some of our ongoing projects. One example of such a partnership, a three-year continuing research study at Bendigo Senior Secondary College analysing the use of new technologies for teaching and learning, will then be discussed. In reporting on this research I intend to present some examples of software programs and student products in different subject areas of the Victorian Certificate of Education (VCE) to give you a specific sense of how these technologies work. The talk concludes with some discussion of research findings and broader implications for the future.

Concerns and Claims in Relation to New Technologies and Learning

Concerns

Commentators have raised many concerns about these new technologies including management and access issues for different learners, and the question of gender differences in usage. Here I would like to consider five main recurrent themes:

1. One area of concern relates to continuing scepticism about whether the use of new technologies actually improves learning at all, or in any dramatic new ways. For example, that well-known doubter, John Ralston Saul (1997: 141-2) was willing to concede that technology 'facilitates our action' but he claimed that this facilitation 'is rarely about more than form', and that often the technology limits our actions to 'its own level of ability'. By this he meant that the new machines or programs only enabled us to perform ‘minor technical manipulations'. Another commentator, Kerr (1996: 11) has noted that claims that regular computer use enhances problem-solving abilities and logical thinking have turned out to be 'largely unfounded'. In the same spirit, Russell (1997:1) cites over two hundred and forty research studies which repeat the finding of 'no significant differences' in effectiveness between face to face learning and various distance education and online programs. For Russell (1997:1) this 'documentation speaks volumes about the futility of these studies'.

However, there are several reasonable rejoinders to these viewpoints. Changing the types of technology used in learning not only alters the form of the learning, in that the roles of learners and teachers are changed, but there is also emerging evidence that the content is also affected. Therefore it is often difficult to compare traditional and new methods of learning, especially if traditional assessment measures are used to do so. Further, Russell assumes, questionably, that learning can be narrowly conceived as the planned specific outcomes stemming from particular programs. By contrast, many researchers are now acknowledging that the use of technologies cannot be simply understood as an add-on tool for learning. Lankshear et al (1997), Bigum (1998), Kerr (1996), Morton (1998) and others, assert that technologies create what Bigum (1998: 15) has called accurately new 'messy assemblages' of people and machines, with new contexts, new ensembles of participants, changed goals, altered procedures, and different networks of relations.

Therefore the nature of the learning and the effects of the technologies are far more unpredictable and complex than previously thought.

2. Another major area of concern refers to the costs and fragility of technology systems and programs. As we know only too well, systems and technologies are expensive, fragile, and costly to maintain and renew, and these issues pose continuous real challenges for schools in terms of system choices and effective maintenance of seamless usage (see Lankshear 1997 et al). Papert (1994) has argued that technologies in schools need to be responsive to emerging business and communicative practices outside class, but the instantaneous obsolescence of equipment poses real challenges in achieving this goal. Certainly universities face the same problem of maintaining currency of equipment so that tertiary students learn to use the systems now deployed in industry, education, and business beyond the university. The question of how much capitalisation schools really require to stay up to speed is still far from being answered.

3. Another concern relates to the fear or suspicion that new technological capacities rather than educational goals drive the curriculum. There is a general consensus (see Hirschbuhl & Bishop, 1998; Kerr, 1996; Lankshear et al ; Snyder 1997; Tannenbaum, 1998) that these technologies should serve rather than dictate educational purposes. Simply because it is now possible for primary school students to email one another across the globe is not in itself sufficient reason for them to do so. However, as Scardamalia & Bereiter (1997) and others have shown, new technologies such as email can serve educational purposes, particularly where students at different sites are required to collaborate on joint projects that are educationally and contextually relevant to them. At the same time, we need to acknowledge that advances in multimedia technologies influence what now counts as effective communication, and hence put pressure on curriculum goals.

4. Another concern relates to perceived negative or undesirable effects on learners' values and behaviour resulting from extended use of these technologies. Will thirteen years of schooling in these technologies produce a generation of technocratic isolates with diminished social skills who have not learnt how to 'function together in society' (Saul, 1997)? Kerr (1996: 7) points out that we do not know the 'long-term impact of regular computer use on deeper images of oneself, one's interactions with others, one's purposes in life, the way the world works'. Many doubts and fears have been raised about the communities and identities produced by a

wired world, and these dystopian technology-driven futures have been explored vividly in such films as *Bladerunner*, and more recently, in The *Matrix*. However, schools are not realistically in a position to turn their backs on the new technologies. Noone these days can plausibly urge a return to the Gestetner. This means that education must explicitly address the values questions that the new technologies raise. These are questions about the effects on ourselves and others of using the technologies, and the need for students to develop a sense of responsible global citizenship in their usage. As commentators (Burbules, 1997a, 1997b; Prain, 1998) are starting to insist, students need both technical know-how and a sense of principled use if we are to avoid producing an age of technocratic opportunists and wired pirates.

5. There are also concerns about the professional development of teachers. There is strong evidence (Lankshear et al, 1997) that this development should be measured in a time-scale of years rather than hours or weeks of in-service programs. Teachers need to be given considerable support in identifying which practices are time-efficient and effective in supporting learning. This does not mean that teachers need to know in advance all the pathways learners might take, but they need to be clear about the learning outcomes they are seeking to promote, and also have some sense of the communicative possibilities of the technologies used, and possible pitfalls and distractions. The professional knowledge necessary to develop student learning within and through these technologies is still in its emergent phase. This means that teachers need to build on their current understandings of effective learning rather than give students too much license to 'play' with the options or pursue their own interests.

Claims for Technology-enhanced Environments

In contrast to the rhetoric of the 1980s, current claims about how technologies work to support learning, or what differences they make, are far more modest and carefully worded. There is now a broad agreement that computers in themselves do not cause learning, because learning depends on the goals and perceptions of learners, 'the kinds of tasks they try to accomplish, and the kinds of intellectual and social activity they become involved in' (Salomon & Perkins, 1996: 113). As well, no single activity affects learning in any profound way, but rather, as many researchers now claim (Bigum 1998, Morton, 1998; Salomon & Perkins, 1996: 113) it is the 'whole culture of a learning environment' that matters. This means that the identification of

the attributes or capacities of technologies in itself cannot provide a complete picture of how they support learning. Rather we need to consider learning demands in relation to the functions and form of technologies to see how the relationship works.

In terms of theoretical accounts of how technologies might serve or contribute to learning, Gibson's (1979,1987) theory of affordances has attracted much recent attention. Various researchers (Burge, 1995; Jonassen, Campbell & Davidson, 1994; Kerr 1996) have viewed this theory as a useful way to sidestep the futile debate about whether technologies cause learning, or merely operate as a neutral vehicle, an add-on tool. From an ecological viewpoint Gibson (1979:127) coined the expression 'affordances' for what an environment 'offers' or 'provides' or 'furnishes' for those within it. Gibson was thinking about animals and habitats, but the idea of affordances can also be applied productively to different communicative systems. For example, speech obviously enables us to communicate, and this form of communication emphasizes the rhythm of the voice and, as countless verbal storytellers have discovered, also prompts powerful personal mental images in listeners. Writing too can encourage readers to form strong personal images, but this communicative system also enables other effects as well. For example, its emphasis on linear logical order allows us to anchor and inspect our thoughts and those of others to a far greater degree than the affordances of speech.

Turning to the affordance of new technologies, it is possible to say that their design functions or purposes provide learners with a rich new set of possible resources to manipulate in order to construct representations of understanding. Powerpoint, for example, as a program designed with synchronous multimodal resources, affords learners opportunities to make and sustain connections across different systems of representation, including textual, visual, and audio meanings, symbols, and patterns. These connections may not seem as orderly or rational to those of us of an older generation steeped in the pleasures and affordances of print, but these new resources have become increasingly prevalent ways to construct meaning at the end of this century. They are also resources that are very congenial to the young. Jonassen, Campbell and Davidson (1994: 37) express this idea of the relation between technologies or media and learning in the following way: 'media afford attributes, which afford cognitive learning activities which afford thinking which afford learning'. Perhaps this should be modified to acknowledge the centrality of curriculum goals as shaping the whole sequence. These researchers also point out that each group of affordances

within this process can affect the learning outcomes, especially the particular technology or technologies used. For example, use of the Web affords students access to a much broader range of resources and learning communities, within and outside the school, but, needless to say, this may result in a mere swamp of information, and does not in itself cause learning to occur. To use the technologies effectively to support learning, learners need to utilise key features such as rapid storage, retrieval and display of diverse information and ideas, as well as multiple and interlocking systems of representation, while they, the learners, seek to interpret, synthesize, and identify and represent meaningful patterns.

At the same time, these new technologies should not be viewed merely as 'neutral' vehicles for constructing and displaying meanings. Every new technology has always transformed the quality, field and potential range of human experience. All new technologies, as Idhe (1990) has argued, shape human intentions, alter perceptions of time, place and space, reduce or enlarge perceptual fields, and refashion every user's sense of agency, field of influence, and scope for action. Therefore, every new technology comes with its gains and losses or constraints, and this also applies to information and communication technologies in schools. For example, the size of the computer screen promotes brevity of text, but its new multimodal resources also enable powerful, emotional webs of meanings. Email enables an addictive spontaneous informality of messages, but can also be used with less positive effect.

Another set of claims asserts that these new technologies increase opportunities for self-paced and self-directed learning (Tannenbaum, 1998; Inglis, Ling and Joosten 1999). For Tannenbaum (1998) design features of multimedia programs such as interactivity and feedback can help individuals learn. Iinteractive programs permit learners to control the timing and content of information flow, with chances for mutual comment and role exchange-ability. Learners can use different senses in responding to various media, and enjoy 'entertaining presentations of the materials' (Tannenbaum, 1998: 28).

These arguments may be persuasive, depending on the context. Restrictive program design may not suit some learners, and technology-enhanced learning environments should offer both opportunities for individual learning tasks as well as shared communal constructions of knowledge. As one student at Bendigo Senior Secondary College said of a teacher's Homepage for electronic self-testing for revision, " It's better to be able to get the feedback straight away when you need it without bothering the teacher". It is certainly

possible to see particular advantages to online material in terms of the needs of individual learners. However, it seems ironic that Tannenbaum should also claim that computer programs will be most successful when they match as closely as possible the advantages of face to face teaching and learning.

Research on Teaching and Learning

Approaches in the Department of Education, La Trobe University, Bendigo

Before considering these claims about technology-enhanced learning environments in relation to Bendigo Senior Secondary College, I wish to turn to the issue of effective university research on teaching and learning in schools. As is often noted (see Kaestle, 1993; National Board of Employment, Education and Training, 1992; White, 1998) educational research in the past has a dismal record of influencing what teachers do or how children learn in schools. There are various reasons for this theory/practice gap. Some relate to the inadequacies of past learning theories, research designs and assumptions, and some are connected to the limited kinds of contact between researchers and teachers, as well as the roles researchers often assign to teachers. For the sake of convenience research in the past often focused on individual learners, thus avoiding the messy and unpredictable complexities teachers face in working with groups. As well, past research projects often saw teachers as mere recipients or agents of research rather than as partners or major players. There have been some notable exceptions, such as the Monash University PEEL project (Baird & Mitchell, 1986) where university lecturers worked over a long period beside teachers in classrooms to develop programs, but this was unusual. Too often university research was a brief raid on the messy complexities of the classroom, and then, in the comfort of the university, multiple psychometric factors would be identified as crucial to classroom learning.

We now have far more comprehensive theories about the nature of effective learning than the behaviourism of the past. Information processing and constructivist accounts of learning (White, 1998) acknowledge the importance of content structure, perceptions of context, and the abilities, prior knowledge, attitudes, and purposes of different learners. We know that effective learning entails learning communities engaged in authentic tasks, where learning is both purposeful activities by individuals and the effects of shared classroom

experiences. This richer understanding of how learning is achieved has prompted parallel changes to the nature of educational research, encouraging more longterm cooperative naturalistic inquiry into actual classroom practices. We now seek to establish and maintain extended research partnerships between teacher education staff and teachers to connect pragmatics and analysis of change. As well, more diverse research methods have been developed, including classroom teaching by researchers, classroom observation, audio and video taping of activities, teacher and student group interviews, and analysis of students' work including maps, models, and multimodal representations.

These changes are evident in research by staff in the Department of Education at La Trobe University, Bendigo, on effective teaching and learning in primary and secondary schools in the region. This research has a strong collaborative focus, with teachers in schools taking the roles of partners or co-researchers in the work. Examples of major cooperative longterm research projects include the following:

1. Literacy Enrichment Program, variously called Focus on One and Literacy for Diversity (1991-99) and currently conducted at Flora Hill Primary School and Quarry Hill Primary School, with Gaelene Rowe, Debra Edwards, and Sarah Mayor Cox (Prain, Rowe, Smith, & Walters, 1992). This program has focused on researching effective strategies to develop primary students' literacy skills, with tertiary students working on a one-on-one basis with primary students.

2. Learning Mathematics in Primary School (1992-99) and conducted at Specimen Hill Primary School, Girton Grammar and Flora Hill Primary School with Steve Tobias (Tobias and Hand, 1995a; Tobias & Hand 1995b; Forgasz, Tobias & Jones, 1997; Forgasz & Tobias,S. 1997; Tobias & Oakes, 1997). This project has researched a range of strategies to enable effective teaching of mathematics. The project has entailed collaborative work with teachers as well as primary and secondary student teachers, with children in different classes using email to share their reflections on learning.

3. Special Education (1998-9) with Dixie Blanksby including the analysis of methods for effective provision of education across the spectrum from gifted to disabled students at Catholic College (Blanksby 1999); and evaluation of the first year of the bilingual program, and recommendations for future practices at Kennington Primary School (Blanksby and Pardo,

1998). This evaluation was considered by the Department of Education to be a benchmark model for similar evaluations.

4. Writing for Learning in Science Project 1993-99 with Brian Hand and Vaughan Prain. (Hand & Vance, 1995; Hand, Vance and Miller, 1995; Hand & Prain, 1995; Prain & Hand 1996a, 1996b) In this project the researchers have observed and taught science classes in junior secondary colleges in Bendigo, as well as participated in many planning and evaluation sessions with teachers. This project so far has resulted in over twenty internationally refereed journal publications, with participant teachers published as co-authors in this research.

5. Use of technology-enhanced learning environments at Bendigo Senior Secondary College, 1997-99.

Research at Bendigo Senior Secondary College

We have established a strong collaborative research partnership with Bendigo Senior Secondary College in terms of joint projects and supervision of College staff undertaking postgraduate studies at our Faculty. Bendigo Senior Secondary College is nationally and internationally recognised as a leader in the development of technology-enhanced learning environments. Since 1995 the College has implemented a whole-school approach to the use of information and communication technologies for learning across all areas of the curriculum. This approach is not easily summarised here but includes the following features. The College established a Local Area Network linked to all classrooms, a Multimedia Centre, and also a management structure to support and enhance information and communication technologies. The College put in place a comprehensive Website, with all learning areas having a homepage, and teachers and students also constructing personal home-pages. All teachers were supplied with laptop computers with access to net-work and large television screens in classrooms, and all classrooms have access to the Internet, the Intranet, library search engines, email, network storage space, and software packages. Students were given home access to electronic files, software, CD Roms, the Internet, the Intranet, and email. In 1998 the College had 350 pentium Pcs, and 2-6 computers in each class-room. The College library was equipped with electronic search engines, and Internet sites were cached to support student study of particular topics in all subjects. Timetabling practices were restructured to include professional development as a core part of each teacher's role, and longer lesson times

were introduced to enable more effective use of the new technologies. Collaborative approaches to teaching and learning were pursued through the College's Intranet hosting of various discussion groups using Altavista as well as on-line listserv discussion groups. These web-based password-protected groups extended classroom interactions and interactions across different classes. Teachers' professional development in all learning areas was promoted through the development of technology plans in each learning area, and an initial focus on skills through inservice programs, then a focus on learning models. Throughout this process teachers were encouraged to develop expertise and initiate new practices in, and take ownership of, these technological resources in developing their teaching and learning.

Aims of Research Project

The research project, supported by a $39000 research grant from the Faculty, had various aims, but I wish to focus on two in particular:

1. to identify conditions including learning environments that maximize effective use of computers for student learning.

2. to identify and evaluate teachers' changing roles, beliefs, and practices in using computers and associated learning technologies to enhance student leaning.

Research Method

An extensive data base of teacher and student practices, attitudes and beliefs has been collected from 1997-99 by Lorraine Boesen, the project's research assistant. This data included findings from survey, interview and classroom observation. Interviews and observations of classroom lessons were conducted with 50 volunteer teachers and some of their students across nine discipline areas (English, Mathematics, The Arts, Technology, Science, Business Studies, Studies of Society and Environment, Languages Other Than English and Information Technology) in the first half of 1997. In the second half of 1997 a more intensive study of 12 teachers' practices was undertaken. Further observations and individual and group interviews were conducted with these teachers, and this was repeated in 1998 and 1999, with opportunities for teachers and students to provide responsive feedback to emerging findings.

Empirical data were analysed in terms of congruence with other kinds of data, including policy documents, student products, staff and student

interview transcripts and classroom observation. Triangulation of data was sought through attempts to identify consistencies across different kinds of evidence, including student performance at the VCE, change to classroom and College contexts and to participant perceptions, and broader surveys of College perspectives and practices compared with state averages. Data-based accounts of teacher and student practices were checked against research reports and research evidence from other contexts.

Contemporary Learning Theory

Before looking at examples of student work I would like to return briefly to the question of the nature of learning in relation to new technologies. We now know that effective learning is an active process where the learner builds his or her own understandings through constructing representations of this knowledge. We know that further learning is the building and rebuilding of these mental constructions and actions about the world. What we bring to each new learning experience, our prior knowledge, is important, but so is what we attend to, and what cognitive and representational resources we have available to us to make and interpret our constructions of meaning. These resources may include relevant subject vocabulary, but learning is also enhanced when we have knowledge of terms for the processes of our own learning, when we understand and can name our own metacognitive strategies. These resources also must include the representational means available to us to build our constructions and to share and negotiate their meanings with others.

Clearly new technologies have the potential to expand the cognitive and representational resources available to learners. This does not mean that the technologies cause or dictate the form or content of learning. Rather they are the potential and actual building blocks of our representations of what we are learning. Multimedia, then, provide environments, resources, that enable learners to construct and represent their emerging understandings. As White (1998: 61) notes, the learner must select for attention only a fraction of what is possible, and this selection 'depends on what the learner knows, and is interested in, his or her immediate purpose, and physical state'. In other words learning always entails assembly, extension, and selective interpretation of experiences and information to construct meaningful and relevant knowledge. Using some technologies will feel like putting on a glove to some learners, but others may feel they are being expected to play

the piano in oven mitts. Effective use of the technologies in learning must then entail opportunities to try out different representational resources. I would now like to look at these issues in terms of specific examples of student work.

Some Examples of The Use of the New Technologies

It is not possible here to cover all the particular and mixed applications used by the fifty teachers across the nine study designs to meet curriculum goals. However, it is useful to look at some specific examples of processes and products to indicate ways that technologies can become part of an enhanced learning environment. Examples have been chosen, not necessarily because they are the most widely used, but to give some practical, informative sense of the processes and outcomes. Some applications such as email discussion groups across classes are viewed by teachers as very effective in promoting learning (see Jordan, 1999; Prain & Lyons, in press), but they are not easily demonstrated in this context or time space. I have chosen five activities, two as applications for promoting learning, and three as student products generated by the new technologies, to give you some idea of the applications in practice and their relationship to constructivist theories of learning.

Graphics Calculators

Graphics calculators are used widely for teaching various concepts in Mathematics in VCE. In this example from unit I of VCE Mathematics Method the calculator is used in conjunction with a motion sensor to generate Displacement/Time and Velocity/Time graphs. As a volunteer student walks towards or away from the sensor a graph of the movement is simultaneously created on the calculator and displayed as well. The program is useful for explaining refined concepts such as displacement rather than distance, and velocity rather than speed. The application can be used for students to replicate a preset graph through walking. The process utilises constructivist learning principles by providing many opportunities for student interaction, participation and analysis of emerging ideas to clarify concepts. However, as one teacher has said, there needs to be an 'intelligent partnership' between the student and the technology supported by algebraic understandings. Simple mastery of an application in itself does not equate with learning, understanding, or new knowledge. In contrast to older methods, students can

visualise concepts more strongly, anticipate, observe accurately, calculate and get immediate feedback on their judgements. Students believed that the application and the actual motion made the concepts easier to understand compared with 'drawing up graphs'. How does it entail constructivist learning principles? The capacity to make and sustain simultaneous connections across graphic and numerical representations, showing how a change in one system affects the other, provides a rich and interactive learning environment.

Student Powerpoint Presentation

The next example is a student powerpoint presentation from the Triple Science Project, where students in teams of six, two from Physics, Chemistry, and Biology, applied concepts from the three subjects to an issue of concern to the community. The four teachers in charge of this project, Barry and Mary Nash, Bruce Carpenter, and Chas Odgers, won the 1998 Department of Education Teacher of the Year Team Award for the best use of new technology in the classroom. The project was nominated for many reasons including the following. It broke down barriers between discipline areas, encouraged teamwork in the application of scientific concepts to a real world issue, developed research skills in the use of the Internet and email for joint construction of meaning, strengthened presentation skills,and also entailed peer evaluation of presentations. There is considerably more information available on the project on the College's Website (http://www.bssc.edu.au) but this short extract from one team in the project gives you some idea of what the students produced through their use of various technologies. The staff considered the project provided effective learning experiences for the students because the learning was context-based in terms of the issue addressed, and because the students had to integrate their understandings into a combined Powerpoint presentation which they then explained to fellow students.

Student Powerpoint presentations are used widely across all study areas at the College, and there is strong consensus between staff and students that this technology enhances student learning, and strong agreement about the reasons why it is more effective than past technologies for a range of purposes (see Prain and Lyons, in press). For example, teachers in all areas commented that the selection of visual and linguistic points for each slide encouraged students to consolidate their understandings, a view reiterated by many students. Student comments also supported findings by other researchers (Snyder, 1997; Lankshear et al 1997) that this technology

increases students' motivation, pride in their work, and engagement with learning. Powerpoint presentations are used by teachers and students to introduce, develop and revise topics, and for assessment purposes, including individual and group presentations. While some staff perceived no change to what was learnt, the diversity of cues when combined with talk and hand-outs was generally perceived as improving learning opportunities. While there might be a danger of student overexposure to this communication technology, the design feature that requires content to be summarised or represented in a limited number of slides is very suited to content-driven subjects in the VCE curriculum.

Computer-based Techniques (Powerpoint, Webpages) for Media Production

The following example is an extract from a video production for Media, Unit 4, by Joshua Hodge, a Year 12 student in 1998. The video was intended to have an educational purpose, using a Monty Python style to teach through humour. Josh shot the video footage, and also took some material from free-to-air television, such as the Win TV News identification. The images of Albert Einstein, the Qantas jet, and the map of the world were taken from the Web, while the image of the Queen was taken from the Coronation Issue of the Herald-Sun. Images were edited on a computer using ADOBE Premier, ADOBE Photoshop, and MacMedia Flash for the animation, with a video card used to convert videotape to a digital form. Technology teachers believed that there were many advantages in students using computers to model and revise their designs in practices that are standard beyond the classroom.

Computer-aided Composition of Multi-Instrumental Arrangements

In the next example from Music, Kathryn Causon, a year 11 student in 1999 studying year 12 Music, uses the sounds of various musical instruments from a synthesiser linked by an encoder to a computer to develop a musical arrangement. The computer displays the tunes as musical scores for each instrument used. This enables students to incorporate the sounds of a variety of musical instruments in their own arrangement without time-consuming organisational problems of hand-scoring then assembling instrumental players to perform the piece. In the following example Kathryn demonstrates how a musical arrangement can be developed in this way using the computer

program. Students perceive many advantages to this process. It simplifies the processing of arranging music, and the instant feedback and ease of entering music encourage experimentation and reward effort. As one teacher noted, "You don't have to be able to play the flute to incorporate a flute'. This teacher also noted that the students learn more by what they hear than by the rules of music theory, and hence there is more focus on teaching the concepts of sound rather than the theory rules. Students appreciated the convenience and creative opportunities of the program. As one student said, "The computer doesn't create the tunes for you. You have to put in your own ideas, but it shows you what they sound like'.

Digital Photograph

The next example is a digital photograph produced by a Year 12 student, Dale Thorpe, for Studio Arts, Unit 3, in 1997. The work, titled Kalwra (Life), consists of 28 panels, and aimed to explore the style and spiritual themes of the Australian painter Leonard French. It was selected as one of the exhibits for the VCE Topcats exhibition in 1998 at the National Gallery of Victoria. Dale used an image of French's stained glass window of the Great Hall at the National Gallery as one element in his composition, and then scanned other images using ADOBE photoshop. The images are segmented into panels to reflect both the interlocking themes and underlying images of French's work, such as angels and fish. For example, in panel 10 we see the top of an angel and the fins of a fish as an interlocking design pattern. Dale thought that the software program provided considerable freedom and scope in experimenting with the construction of the design in that it was possible to go backwards to review past decisions, something that cannot be done with conventional drawing. He also saw the retrieval and reprinting of the image as a positive feature. For example, the original photograph had faded in sunlight but could be reprinted on superior quality paper for the Topcats exhibition in Melbourne. Another feature of the program, the possibility of multiple layering of imagery, and scope for varying the opacity of each layer, enabled complex effects such as the stained glass image being laid on top to give the effect of light shining through the window. His teacher believed that the capacities of the program encouraged diverse independent exploration of images. She did not consider that all Art students should be compulsorily required to use this software but rather that it could be a valuable resource for some students after they had done some initial work with Powerpoint.

Research Finding

1. Conditions including Learning Environments that Maximize Effective Use of Computers for Student Learning

Our research suggests that many conditions are important. These include teacher knowledge about the capacities of the technologies, and effective choices in learning activities. There is also the question of which particular applications best serve individual self-initiated learning, and which are suited to more group-oriented processes. In this regard the theory of affordances provides a useful way to understand these choices and opportunities.

Teacher and student comments indicated that some technological applications were perceived to have affordances that were especially effective in enabling students to meet prescribed curriculum learning goals. This is particularly the case where the technology enables the user to manipulate diverse options to construct his or her own design or interpretation, as we saw in the examples of student work. This seems more effective than the alternative of teacher-designed instruction, where teachers dictate learning pathways, rather like designers of a golf course on which students learn to play. These findings clearly have implications for effective online learning in that students need opportunities to construct understandings rather than be the passive recipients of expert advice.

It is also worth noting that some software programs have design features that enable users to create products or perform analyses or calculations that exactly match the specified learning goals in some VCE subjects. For example, the purpose-built design elements in Illustrator (Graphic Design) Ashlar Vellum Software (Technology Design and Development) computer-aided composition of multi-instrumental arrangements (Music Performance) and Graphics Calculators (Mathematics) are perceived by both teachers and students as providing significant learning advantages over past methods or resources.

However, this raises the question posed by Gee (1996, 138) of distinguishing between acquisition or mastery of a skill, and learning, or 'conscious knowledge'. While clearly some technology uses promote acquisition skills, and this acquisition can be an important part of developing learning, this mastery in itself does not automatically signify learning. At the same time, there is strong evidence of improved student academic performance across all subjects from 1995-8 at the College. This improvement includes performance at the A+ and

A levels which specify learning outcomes that represent higher order thinking and synthesis skills. This is not to argue that this performance improvement is directly caused by the technology use, because staff have also undergone extensive professional development programs, and other changes have also occurred in the College's resources, staff profile, programs and organisation over this period. However, it seems reasonable to view the use of the technologies for teaching and learning as a strong positive factor in providing affordances for student thinking and learning.

2. Teachers' Changing Roles and Practices

As with earlier studies, many teachers believed that their roles changed considerably in using the technologies for teaching and learning. Rather than directing the whole class they saw themselves as facilitators, monitors, guides, individual problem-solvers. As one teacher commented, "Instead of conducting teacher-centred lessons with talk and chalk, I now am more likely to set the parameters, monitor individual performances, and act as a mentor or problem-solver for particular students".

While it was assumed that the introduction of technologies would lead to increased teacher sharing of resources, there was a very strong pattern of collaboration between teachers in preparing and sharing resource material and problem-solving in teams. There has also been increased collaborative work between students, with increased group work in a wide range of classes, collaboration across classes in joint activities and on-line discussion groups, and collaboration between schools with e-mail exchanges across states and countries. Students are now more likely to know and seek help from teachers who are not their assigned subject teacher, because of these group practices. Both teachers and students perceive they are working in a broader context with much more scope for support from within and outside the College.

3. Unintended or Unexpected Outcomes

Introduction of the technologies also resulted in various unexpected outcomes. These included changes to the learning environment, such as the form of learning, work patterns and interactions, and organisational groupings, and also changes to the content of learning. Content is here defined as both procedural knowledge in using the technologies as well as additional concepts and higher order understandings.

Changes to the Learning Environment

Various changes occurred to the learning environment relating to resources and patterns of usage of the technologies. For example, the Intranet had a much larger effect on the content and teaching methods across all learning areas than was expected. The capacity for storing current material and the speed of delivery of this material altered classroom practices, with an increased use of electronically-held material for student topic work. The teacher and student experiences in using the technologies in scheduled classes also led to changes to timetabling, with longer periods introduced to accommodate more effective access to the technologies in class. Staff also saw the value of on-line delivery of the curriculum, especially in supporting students in revision work through access to Intranet materials. Again the challenge here was to make this learning student-oriented rather than rely on teacher transmission of instruction.

As Lankshear, et al (1997: 48) have argued, learning in the traditional sense was based on the notion of 'nested boundaries', with the book enclosed within a classroom enclosed within larger curriculum structures. However, as both teachers and students in the study noted, the introduction of the new technologies meant significant changes to each of those enclosures, a different sense of space and interactions for learning, and a different sense of the temporal dimension in which this learning could take place. Certainly in the view of the teachers and students much learning now occurred outside class time, and the introduction of the new technologies had created more diverse pathways to support this learning.

Changes to Content of Learning

Teachers were divided about whether the use of the new technologies meant that students learnt new content. There was disagreement both within and across all subject areas. Teachers who thought the content had not changed argued that the key concepts remained the same, but that students learnt the concepts more quickly or that the old content was covered in more diverse ways, or that the technologies made this content more 'succinct' and easier to learn. As one science teacher explained, 'traditionally, students have understood the content poorly, but it appears to be more clearly understood by using these processes'. Teachers who considered that the use of the technologies altered what was learnt claimed that the technologies changed students' perceptions or the breadth of information to be analysed. For example, an Arts teacher claimed that

the technologies 'offered a range of effects that students might not have considered', and therefore promoted deeper understanding. A history teacher argued that through the Internet 'students can discover more diverse, less filtered information' whereas 'historical reference books usually have mainstream interpretations of the period in which they are written'. Teachers in Technology Studies believed that the programs altered students' perceptions of various aspects of design when contrasted with past methods. One teacher in English believed that the current assessment focus on language in this subject failed to acknowledge the visual dimension of some texts with illustrations, and also failed to acknowledge what students had learnt about non-linguistic communication. All teachers who perceived changes to what was learnt in their subjects considered that the new technologies encouraged students to explore the traditional content in far greater depth.

If we accept Idhe's (1990) argument that use of new technologies always alters the perceptions and sense of purpose of users, then it is reasonable to suggest that the new information and communication technologies will affect the procedural knowledge and understandings of learners. At the same, time the highly prescriptive nature of the current VCE, with its set learning outcomes, encourages teachers to focus intensively on this aspect of learning rather than these other effects. One Information Technology teacher noted that the Board of Studies currently restricts the particular technologies that can be used in this subject. This practice is justified in terms of maintaining equal opportunities for all students in the subject; however, such a view also implies that the use of different technologies leads to marked differences in students' products, and hence affects also what students learn from different processes.

Future Implications

There any many implications from these emerging findings, but I would like to focus on three that are crucial for the future. I have argued in this presentation that the intentions of teachers and students are the most crucial factor in student learning and in the development of an effective technology-enhanced learning environment, even though the technologies influence both the content and the form of learning. Our research suggests that there are various important issues to consider in developing such an environment. These include a model of learning that recognizes not only a linguistic, numerical or logico-analytical emphasis, but can incorporate

more multimodal learning processes that take into account visual, aural, and somatic aspects. Another important issue in this learning environment is the effective sharing of resources of staff and students within and beyond the school. As we saw in the work at Bendigo Senior Secondary College, this can be achieved partly through teachers working in teams and also through effective use of knowledge-sharing through the technologies. A further issue is the effective provision of both individual and shared learning experiences. Each of these issues also represents a challenge for the development of effective online teaching and learning, as well as for effective learning in tertiary contexts.

Another implication concerns the development of students' critical awareness of the effects on themselves and others of the new technologies. This entails more than understanding and deploying an etiquette of use, of learning how to 'behave in cyberspace' (Mendels, 1999). As Burbules (1997a, 1997b) and others emphasize, students need to go beyond current critical practices of checking the credibility of writers or designers, of gauging the expertise, impartiality, or coherence of what is offered, and distinguishing between information and knowledge. Students also need to learn and appreciate their responsibilities as future global citizens of a wired world. How such understandings might be taught effectively remains a future question for teaching and classroom-based research. However, such learning needs to become a more central concern of the curriculum.

Finally, there is the continuing implication of how teachers can be supported in understanding and using new practices. As indicated in our research, the effective use of new technologies represents significant new demands on teachers' expertise in structuring effective teaching and learning. While there is still much mapping of desired outcomes and appropriate teaching methods to be undertaken, our research indicates some important principles about how this professional development might be achieved. Clearly there is a strong need for cross-curricular support and in-service programs of the kind initiated at Bendigo Senior Secondary College. Our research indicates that this teacher development can be achieved by systematic collaboration between teams of teachers and by partnerships between schools and teacher education Faculties that focus on classroom-based research into best practices. While we still do not have extensive research-based findings on which practices best support particular or broad learning goals, the development of such knowledge is likely to be achieved through collaborative work of the kind outlined in this presentation.

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