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MetaMaps — Assessing understanding of large, complex or distributed knowledge domains.

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Abstract

Traditional assessment and evaluation instruments and procedures are usually tied to specific, limited content and knowledge. Evaluating learners' understandings of wider and more complex knowledge systems requires a different approach. MetaMaps provide an alternative approach to the linear essay, term paper or minor thesis for evaluating students holistic understandings of complex knowledge systems. For the student they have the advantage of being developmental, allowing for the ready inclusion of developing knowledge and perspectives and they make the learning-evaluation cycle more holistic by using the MetaMap as both a learning and assessment tool.

Keywords

Assessment, evaluation, database, knowledge systems, visualisation, representation, hypertext

1 INTRODUCTION

We are developing the Research in Computer Education site (RICE) to be a collection of information that is relevant to the needs of practicing and trainee teachers. We wanted to design a place where they could engage in professional development activities, including engaging with the research literature on the use of computers in education. We are endeavouring to organise the information in a useful and innovative way to enable teachers to purposefully use our site; not just surf through, but stop, look, read, reflect on, discuss, apply and link. We are investigating the possibility of constructing pathways or maps through the information in order to help the user. The idea is not to construct pathways which everyone must follow, but to enable the users to construct their own maps.

While our initial ideas for the functionality of a mapping or 'visualiser' tool came from this pragmatic need, our ideas of software development came from our primary focus on the processes of learning and teaching; we are not trying to make a better 'bookmark' manager, but a cognitive tool. The 'Meta' feature of the Map allows the users to plot a pathway, look back, write notes on where they have been, plan the way ahead and stop and think and make notes at any stage of the journey. It was intended that the MetaMap would be a utility that would be used to access the Internet in a more purposeful way with a tool to take notes, make links, reflect, revisit, stop at any point, and generally be there to support the user.

2 THE METAMAP CONCEPT

MetaMaps as we now conceive of them (Johnson, 1995; Nicholson & Johnson, 1995) overlap with many areas of current research such as the visual representation and mapping of large, n-dimensional distributed systems, object-database design, cognitive research on semantic and concept mapping (Fischer, 1992; Novak, 1982; Novak, 1981; Novak, 1990b), hypertextual practice (Rao & Turoff, 1990; Reynolds & Dansereau, 1990), metacognition (Borkowski, 1992; Fortunato & Hecht, 1991; Novak, 1990a) and the literature on reflective practitioners (Baird, 1987; Baird & Northfield, 1992). Diana Laurillard's (1993) model of cognitive interactions between the world views of the learner and teacher are highly relevant here. We have drawn part of our ideas from this rich literature, but have primarily adopted a pragmatic approach in developing concepts for a 3-dimensional graphical user interface which is designed to facilitate the learning of students exploring complex knowledge spaces. In our initial planning, a number of basic design considerations arose which provide an overview of the complexity to be addressed, even at the initial stages. (Johnson, 1995; Nicholson & Johnson, 1995). Our software developer, Andrew Smith, has made a major contribution to the following discussion (Smith, 1995), and has greatly assisted us in clarifying our ideas. Our shared design ideas are discussed below to provide a lens on some of the aspects of the MetaMap design and purpose.

This discussion focuses on our initial plans to use the MetaMap interactively with a web browser. In the following section, we discuss how we have used it as a stand-alone learning and assessment tool. We initially thought of the MetaMap as a two part tool; an 'annotator' and a 'visualiser' (Nicholson & Johnson, 1995). We thought of the annotator as a replacement for Apple's Cyberdog Notebook, and the Visualiser as being a replacement for Cyberdog's simple Log. The Log keeps a rather limited record of where you have been on the World Wide Web and gives you three ways of viewing that record: alphabetically, chronologically and hierarchically. The alphabetical view continues to be useful as an aid to finding things that you remember by name (lexical organisation). However if the chronological and hierarchical views are combined into a single interactive image, then there might be the basis of an effective visualiser component. First consider a **chronological view** of a log (figure 1) where a user has recently visited five pages:

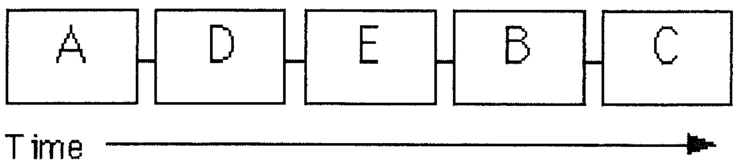
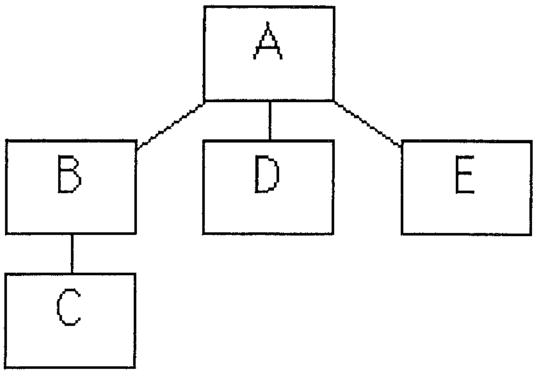


Figure 1 Chronological representation of a log (Smith, 1995)

This view accurately models the user experience but communicates little about the organisation and context of any information structurally richer than a slide show. Contrast this to the 2 dimensional **hierarchical view** (figure 2a) which supplies the organisation of the information reviewed by the user, but does not accurately reflect the user experience. Figure 2b describes the same structure using the Apple's **3 dimensional virtual reality paradigm.**



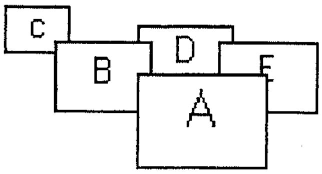


Figure 2a Hierarchical view (Smith, 1995) **Figure 2b** 3D 'VR' view (Smith, 1995)

Combining the two views into a single network view gives figure 3:

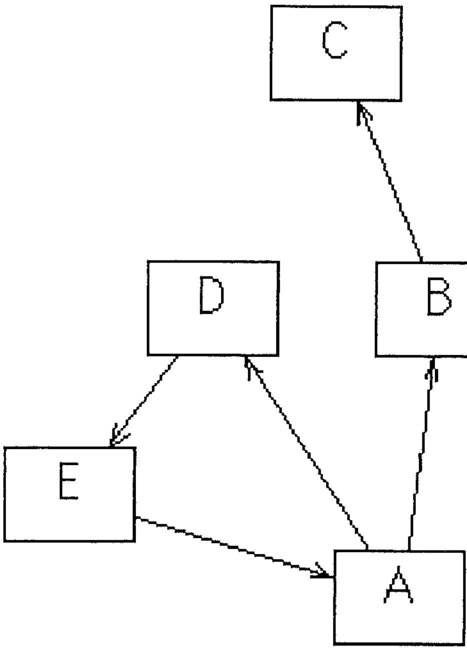


Figure 3 Network view from chronological and hierarchical views (Smith, 1995)

A three dimensional version of figure 3 would require something like Apple's Project X (figure 4) but with a ribbon linking the visited nodes together. The ribbon would include directional and perspective cues, and it would probably require animation to successfully convey the information.

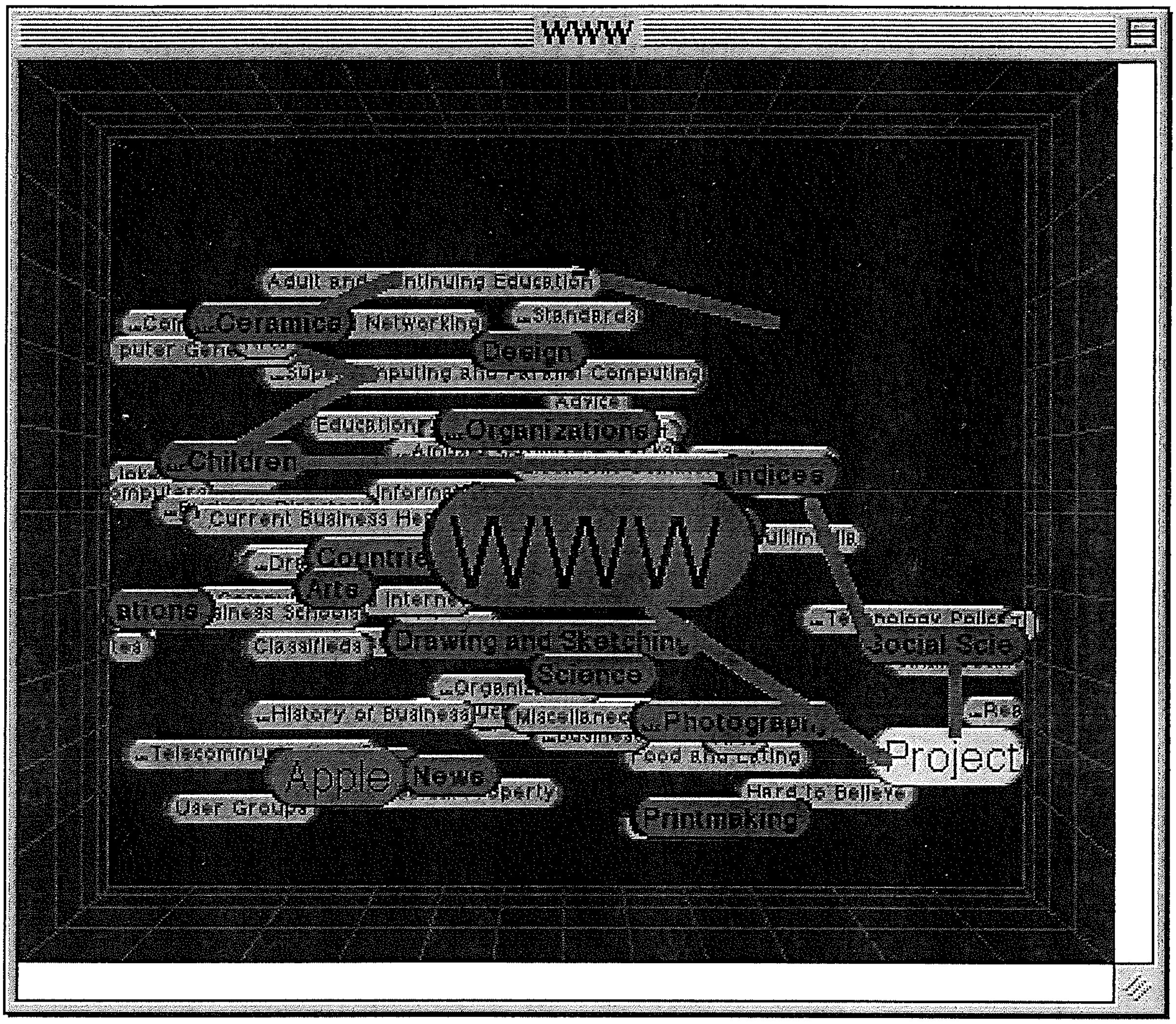


Figure 4 Basic mock up of Project X based MetaMap (Nicholson & Johnson, 1995)

If you imagine each box to be a Cyberdog item (URL) then it is an easy step to picture the diagram being created automatically (as the Log now is) as you navigate through web space. Later, you could select a portion of the resulting image and copy it to another document, or manually remove elements, or add and link them by dragging from the annotator/notebook — Visualiser links do not necessarily have to reflect the links that are built into the web pages themselves. Now suppose that even more information was stored than is currently retained by Cyberdog's Log. For example, if every access to a particular URL was retained, rather than just the most recent, then it would be possible to represent whole web-surfing sessions graphically as is depicted in Figures 5a & 5b:

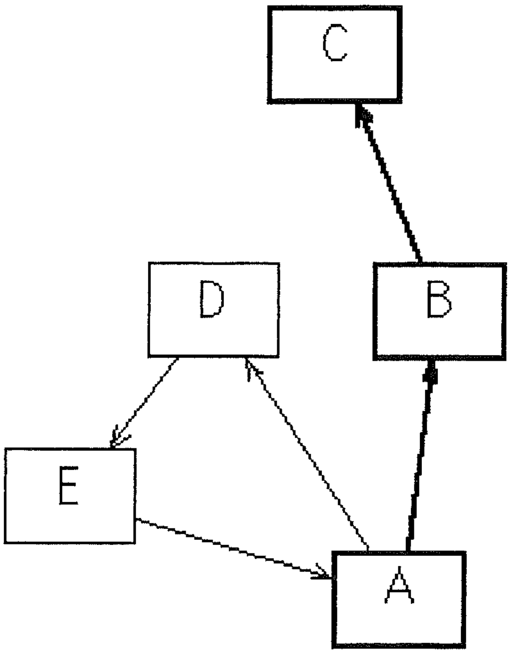


Figure 5a Session 1 data traversal

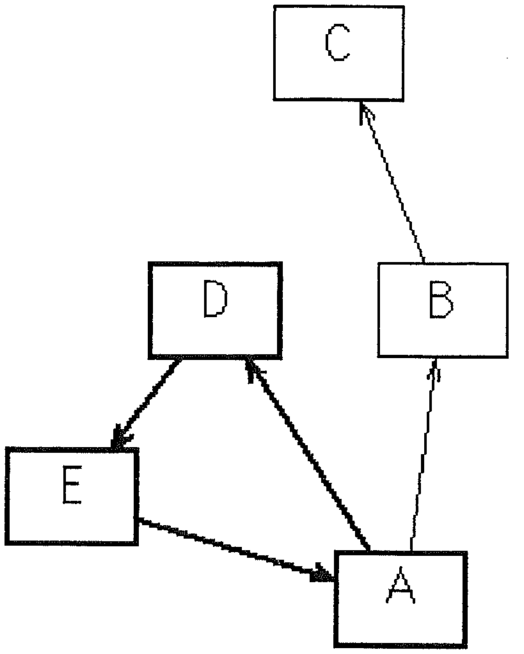


Figure 5b Session 2 data traversal

Each session could correspond to one of the tours which are described in the MetaMap notes. With the addition of a few simple manipulation functions, and the ability to annotate nodes and links with arbitrary live objects, a complete authoring environment for MetaMap tours would be possible.

Finally, dynamically combining the Visualiser file with the meta-content files available at an increasing number of web sites would give an arbitrarily broad and current context for any lesson or visit generated using these tools (figure 6). In this model we can see the emergence of the power of the MetaMap as a tool for navigating complex systems, and for recording the details of those visits.

However we are more interested in its power as a tool for linking written text—reflections and research literature as a mind-tool for working with large amounts of educational research data, curriculum, and related materials.

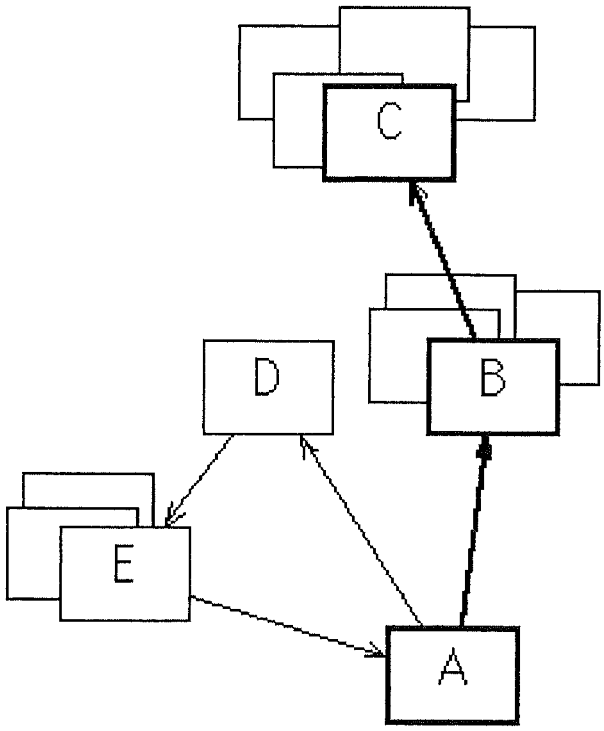


Figure 6 MetaMap based on a Visualiser file and site-based meta-content files

3 STAND-ALONE METAMAPS

In our MetaMap pilot project, we wanted to assess the suitability of the model and the notion that students trained in the traditional linear assignment could, and would, adapt to the challenges of the MetaMap approach. The pilot group was a postgraduate class studying the topic of 'Technological literacy'. This seemed an ideal environment for trialing the MetaMap.

A prototype MetaMap using a web form was developed using NetForms™ (Maxum, 1998). Nine general areas were included in it as the basis of the map: author's comments, topic details, reflections, research, curriculum, issues, evaluation, converging technologies and 'other'. This simple technology and limited categorisation were used because it was quick to develop, allowed on-line entry, was editable on-line, and automatically created a hypertext document, published it, and created an index file to it.

In addition, it allowed students to embed HTML links between and within text in each category, and to external sites, thus providing some of the basic functionality of the original MetaMap design. This would allow the students to explicitly make links (both physical and cognitive) between the data in each category. This has a strong similarity to semantic-mapping and concept-mapping, but occurs as an embedded feature of the data collected by the learner, thus enriching the data rather than overlaying, or standing outside it. It meets, and perhaps extends, some of diSessa's concerns about 'transparency' and 'reconstructibility' in a textual, as against programmed, environment (diSessa, 1985; diSessa & Abelson, 1986; Nicholson, 1994a; Nicholson, 1994b).

The students were challenged by the notion of a MetaMap, and initially wanted to return to a linear essay format. However when the value of the map as a notepad, 'thinking place' and learning tool became apparent, they began to value it. They were especially enamoured of the fact that the learning and assessment processes were seamless — learning occurs through building and refining the map and its links, and assessment is submitting the finished map.

For the first time I was able to submit an assignment that allowed me to demonstrate my mastery of a rich, complex knowledge domain, and to represent the interactions existing in this area in a meaningful way ...and in a way that demonstrated my personal understanding of the interdependencies.

A feature of these first MetaMaps was that they appeared to support some of our suspicions as to how students engaged with a complex area such as 'technological literacy'. In the early stages, the maps were being filled with brief references and abstracts, with few, if any, links to other items. This first stage lasted about 5 weeks. After this, there was a sudden rise in the amount of reflective writing, and a corresponding rise in linkages in, and across categories. We feel, in a most informal and formative sense, that this is an issue that needs to be formally researched in order to identify what actually was occurring. We question, for example, if it might not represent a shift of state to a higher level as in Perry's models of thinking?
The student reaction to these, what we initially saw as simplistic maps, was surprising. Additionally, the maps themselves, while highly variable, demonstrated the value of hyperlinked text as a way of learning about a complex field, and as a tool to assess such holistic learning.

4 ASSESSMENT AND EVALUATION ISSUES

MetaMaps embed a strong constructivist approach to learning within them. Our informal observations of groups of students arguing over MetaMaps, suggests that socially constructed learning is very significant here (Bandura, 1996), as are pertinent teacher interventions. The fundamental problem in assessing or evaluating a MetaMap constructed through a social learning process, is that is someone else's map of a complex field, and it reflects what they see as important, relevant and authoritative in that field. It is almost a personal statement of understanding. Unlike with a traditional 'objective assessment' instrument, the MetaMap is not able to evaluated in a simplistic, low-level way. This is axiomatic in fact, because of its application to complex, dense and/or distributed knowledge systems. It would be quite amazing for a tool to produce a reductionist version of such a field.

.How do you assess a MetaMap? How do notions of 'accuracy', 'scoring', 'validity' and 'reliability' apply here? More importantly, how do you assess a MetaMap that develops a coherent perspective from an alternative epistemology, or one which draws on knowledge from different fields than those that were expected to be used? A holistic approach is required, as the task becomes much more akin to assessing a minor thesis (although on a much smaller scale), than marking an essay. MetaMaps are also frustrating to assess when you want a quick result. They usually cannot be assessed quickly, but if that was our goal, we never would have developed them.

We have adopted a holistic approach to marking MetaMaps when used for course evaluation purposes (as opposed to developmental or exploratory learning). In this approach, the maps have been reviewed by the lecturer, and comments made for the student to consider. There is opportunity for response, and academic argument about the interpretation of the map. Finally there is a negotiated agreement as to how well the MetaMap covers the field or topic of concern. This is time consuming, but not all that much more than is required in marking formal essays, especially in course teams where cross-marking is required.

5 DEVELOPMENTS

The next stage in our MetaMap development is to begin to implement our original model as discussed previously. This will involve the creation of dynamic MetaMaps with a graphical interface, based on a database structure rather than web-forms, most possibly Apple's Web Objects database technology, thus preserving our original intent to link this closely to web, and hence document, browsers.

Concurrently with this process, we plan to conduct a formal research study into how students create, use, and learn from, MetaMaps in order to better inform ourselves about appropriate evaluation strategies and perspective's.

An unanticipated benefit of the technology provided us with a formative view of the students' work, when previous versions of the MetaMaps were archived on the web server. The series of maps may provide us with valuable data about the students' learning processes, and hence solve some of the questions we seek answers to about how to evaluate their MetaMaps.

6 CONCLUSION

MetaMaps are potentially a powerful teaching and learning tool that enable learners to incrementally tackle the challenges of mastering large, complex knowledge domains. Our initial work with the 'low-level' forms-based version shows that they are a tool that can be created at a variety of levels. The greatest challenge to be addressed is 'how and why' to assess the map as an entity, and the 'content' in it. It brings new meaning to the term 'realistic assessment'!

7 BIOGRAPHY

Paul Nicholson lectures in computer education and science education at Deakin University. His research interests are in the areas of teacher education, professional development, cognitive theories and converging technologies. He is a co-founder of the Research in Computer Education group at Deakin, and an active researcher. He has published widely on issues about the application of computers to teacher education, and to schooling. Current projects include developing a national professional development delivery program over EdNA - the Education Network of Australia, and trying to build a better MetaMap program.

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GENOVA

Design and Reporting on Research Projects Based on ICT

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INTRODUCTION

Our research activity centres on the construction of models for the design and use of software systems that support teaching and learning processes within schools and in continuous training of personnel employed by small and medium enterprises (SMEs). The discipline of interest within the school context is mathematics, while the continuous training concerns technical innovation in the workplace, especially offices. Hence, our research is part of that vast area devoted to the study of the conditions affecting learning of a particular discipline, and/or of target knowledge identified within a system of constraints (the education system) made up of one or more institutions dedicated to fostering and evaluating that learning.

It is well known that an educational system is constantly subject to a set of constraints that restrict the development of the teaching/learning process, in the sense that they steer and drive it. The limitations that affect the educational system are usually expressions of tradition as well as entrenched educational and organisational practices. They are determined by social and cultural factors, and as such are subject to change. Indeed, educational systems may be affected by transformations taking place within society and culture, and likewise the inherent constraints may also be changed in response in order to bring these systems closer into line with the transformations taking place. These constraints vary in nature, and include temporal constraints (learning must take place within a certain time limit fixed by the institution), logistical constraints (available resources), organisational constraints (characteristics of workplace organisation), constraints related to the type of knowledge to impart (acquired knowledge must conform to reference knowledge governed by the institution), constraints imposed by student characteristics (age, school level, previous experience,...), constraints brought about by the social need that represents the reference point for the training process (made plain to a greater or lesser extent by the institution). Influenced by social and cultural stimulus and pressure, these constraints may be subject to changes that bring about transformation in the teaching/learning process.

In recent years, the computer has proved a vital tool for stimulating change within education. The technological revolution currently taking place in society has put enormous pressure on education systems worldwide, forcing them to respond to the demands that change is bringing about in society. Our research is set against this background, and focuses on the role that information and communication technology may play in teaching and learning processes (where it may act as a mediator in the acquisition of important skills and competence), as well as on evolution in the education system.

In this paper, we shall propose a methodology for the design and reporting of research projects involving computers in education and training. This methodology has been applied within a number of research projects conducted by our institute and in this paper we shall examine three of these. They involve the application fields of the school and of continuous training. The former is the setting for two projects that differ substantially in nature: the first regards the design, implementation and experimentation of a system that has been created specifically as a support for mathematics learning, while the second concerns analysis of the effect on curricula and learning processes brought about by the use of commercial software applications not necessarily intended for educational purposes. The project concerning continuous training looks at the design, implementation and experimentation of a system for developing office automation skills in small and medium enterprises. The differing attributes of the three projects help to give a clear and detailed picture of the characteristics of the methodology used for designing and reporting projects based on the educational use of computers.

THE SCHOOLING AND TRAINING SYSTEMS

School education and continuous training in companies represent two faces of education that share some characteristics but differ in others. The main differences regard constraints related to the knowledge to impart, the student profile and the context.
In the school system, the constraints regarding the knowledge to impart are fairly apparent in that the knowledge itself is usually clearly defined. The process leading to identification of the knowledge to impart, beginning with reference knowledge, has been studied by Chevallard ("transposition didactique"). In continuous training in companies, constraints of this type are much less apparent. This training arises out of social needs that have to be taken into consideration in each case according to the particular workplace in which the learning is to be applied. As we shall see, this has implications for the methods adopted in designing and using technology-based systems for education and training.

School students are not usually aware of the learning domain within which they have to perform technologically-assisted tasks, and acquiring this understanding is the objective of technology-mediated learning. By contrast, participants in continuous training devoted to office automation usually have extensive know-how in the knowledge domain of the tasks to be mediated by technology. Hence, the role played by the computer in these two contexts in profoundly different: it should help to put school students in touch with the concepts involved in the task domain, while in continuous training the computer represents a tool for carrying out tasks whose purpose is clearly understood by the participants.

The schoolclass represents a real context of reference for the development of relationships and interaction for learning and the evaluation of that learning. Conversely, continuous training takes place within courses that are held outside the context where the learning will be applied and evaluated. In both cases, technology-supported learning alters the kind of co-operation established between all those involved in the learning process. In the case of continuous training, the use of technology may even modify relationships within the workplace, bringing about changes in the level of interpersonal co-operation and even in the power structure of the organisation itself.

CHARACTERISTICS OF THE METHODOLOGY USED

Research methodology is always based on fundamental assumptions that are part of the methodology itself and help to focus and guide analysis of the matter to be studied. In our case, the basic premises and assumptions concern (i) the role of the user, (ii) the role of the software systems with respect to the type of learner involved in computer-mediated education and training, and (iii) evaluation of these systems.

- Software used in education and training addresses two kinds of user: teachers or tutors, and students or employees. Teachers and students play different roles in software use. The role of the teacher is to provide assistance for the student during activities, to design learning paths that lead to effective learning of a given knowledge area, and to evaluate this learning process. The role of the student is to carry out the problems that comprise the activity set by the teacher.
- Software functionality must address the specific requirements of these two different but complementary user categories. The student needs to have at hand representation and operation tools to tackle and solve problems, instruments that help him/her gain awareness of

the strategies involved, thus helping to create a link between the learning process and learning object. The teacher's needs are to have at hand tools for monitoring the activity and for providing the necessary assistance to students.

- evaluation of software for education and training purposes must not be limited to the technical aspects of usability and user-friendliness, but must centre largely on its usability and usefulness for learning. In other words, system evaluation must take into account all the elements that affect the process of learning knowledge (and not just those related to learning the system).

In the light of these assumptions, the methodology used in the design and reporting of computer-based educational research projects allows us to study the changes to be made to educational system constraints, the aim being to guarantee efficient learning based on the identification of the computer's conditions of use. In our view, this can be done by carrying out analysis that covers three strictly related levels: the **epistemological level**, related to the objects of learning and to new ways of attributing meaning to them through computer mediation; the **pedagogical level**, related to new ways of structuring activity through computer mediation; and the **social context of use level**, related to changes in roles, social interaction and forms of assistance that arise in computer-mediated activities.

Clearly, these different levels are not distinct but, rather, strictly related. For example, the meaningfulness of the new possibilities that the computer presents on the epistemological level can be related to two aspects: the specific characteristics of the interface in terms of the knowledge to be learned; and the social context of use that helps in structuring a learning practice that efficiently exploits the system for learning purposes.

In the following, these three levels have been dealt with separately; this has been done purely for the purposes of describing the application of the methodology to the three case studies presented.

THE FIRST PROJECT

The first project concerns the design, implementation, experimentation and evaluation of a system called ARI-LAB. This system is aimed at developing arithmetic problem-solving skills at primary school level.
For a general discussion of critical issues regarding the design of educational software and, in particular, of computer-based cognitive tools for problem solving we refer to (Reusser, 1993). Design of the ARI-LAB system was based on research results in the fields of mathematics teaching, educational computing and HCI, within a more general framework that also embraces cognitive and semiotic research. In particular, we refer to Vygotsky's notion of cognitive tools (Vygotsky, 1978), objects provided by the learning environment that permit students to incorporate new auxiliary methods or symbols into their problem-solving activities that otherwise would be unavailable.

In the following, we describe the project in terms of the three levels outlined in the previous section. However, before doing so it is worth taking a brief look at the main characteristics of the ARI-LAB system.

Brief description of the ARI-LAB system

ARI-LAB is a system consisting of a structured and interconnected set of different environments that offer the user various functions for solving arithmetic word problems. Two different kinds of user are foreseen: the student who has to solve a given problem, and the teacher who has to assist the student during his/her activity and promote the acquisition of arithmetic knowledge.

The student can access four main environments: *the visual representation environment, the strategy building environment, the communication environment,* and *the database environment.* In addition to the environments available to students, the teacher can access a further environment called *the teacher environment*, which allows her/him to set different layouts of the system in accordance with learning goals and the specific needs of the students involved. In the *strategy building environment* the user can choose an arithmetic problem text and build the solution to that problem. To construct the solution strategy, the student can use verbal language, arithmetic symbolism and different graphic representations that can be obtained in the *visual representation environment.* This environment provides representation systems embodied within a number of microworlds. The microworlds currently available are: "abacus"; "coins"; "simplified spreadsheet"; "calendar"; "histogram maker"; two different microworlds for integer division, "quotation division" and "partition division"; and a microworld called "art bits" for the free production of drawings.

When one of the available microworlds has been selected, the user can activate different functions to obtain visual configurations representing the problem situation or a resolution step. When, through interaction with a microworld, the user obtains a visual representation that suits her/his goals, s/he can copy it into the strategy building environment, possibly with the addition of verbal or symbolic comments. When a solution to a problem is obtained, it can be stored in the database of solved problems. Users can access the *database environment* when they want to view previously solved problems that have been classified by the teacher, or problem solutions they themselves had previously saved (their own solutions or solutions received from other users). The *communication environment* allows pupils to link up via network and exchange written messages and problem solutions. The *teacher environment* allows the teacher to set different layouts of ARI-LAB according to her/his educational preferences.

ARI-LAB system has been widely experimented with in different classroom situations both with able-bodied and disabled pupils (deaf).

Epistemological Level

The mathematical knowledge involved in learning arithmetic at primary school level entails development of the number concept and the capacity to use procedures, arithmetic symbols and strategies for solving addition and multiplication problems.

The traditional approach adopted in compulsory schooling is mainly based on: 1)introduction of numbers according to positional decimal notation based on deciphering and coding, usually without consideration for the numerical skills of the student; 2) early introduction of arithmetic signs as the only way for making the resolution procedure explicit in problem solving; 3) early introduction of written calculus algorithms of arithmetic operations used as a means for reaching a solution to a problem. The result of this approach is that primary and middle school students often experience great difficulty in solving arithmetic problems. This difficulty often derives from the inability to associate meaning to arithmetic symbols. This may lead the student to try to guess which operation to apply to the situation, totally losing sight of the relationship between the problem situation at hand and the meaning of the symbols that can quantitatively interpret that situation. These matters raise important educational issues about the most suitable methods and methodologies for developing, say, mastery of arithmetic symbols and symbol systems in general.

An educational approach that pays due consideration to symbol meaning should not expose students to the use of arithmetic symbols until they are able to produce resolution strategies using other systems for representation and semiotic mediation, systems that are more effective in supporting control of the sense of the strategy applied in relation to the enunciation of the problem.

The ARI-LAB system was conceived with this aim in mind. It was designed drawing on the results of research into microworlds, direct manipulation interfaces and network communication systems. We worked on the basic assumption that, in specific conditions, microworlds with direct manipulation interfaces may grant access to knowledge through integration of the perceptual-motor and symbolic-reconstructive approaches. In particular, systems may be constructed that operate on the "computational objects" belonging to microworlds. During interaction with the computer, these assume the status of symbols of a representation system with its own internal rules. The ARI-LAB microworlds offer students fully controllable resolution instruments based on their personal experience. These are able to bring to light correctly the various mathematical strategies involved in problem solving, drawing on the patrimony of experience that students build up both in and out of school. All of the resolution strategies that can be adopted in solving addition and multiplication problems (part-part-total,

total-part-remainder, completion, partition, quotation, etc.) can be reified using microworlds and therefore controlled at a perceptual-motor level.

Pedagogical level

In order to analyse the project at a pedagogical level, it is necessary to study the mediation that the ARI-LAB system offers in the structuring of the learning activity. This means considering the mediation the system offers in acquiring skills for arithmetic problem solving - not in relation to individual tasks or problems that the students are set, but rather in relation to activity cycles designed and implemented using the system.
For example, one of the activity cycles followed in experimentation with the system regards the development of skills in writing numbers in decimal positional notation. The main difficulty here lies in the transition from an additive conception to a positional notation of numbers. In this transition, epistemological problems surface which have an effect at both the phylogenetic and ontogenetic levels and that are constituent within the new knowledge to be learned. With the help of the ARI-LAB system, an activity cycle was constructed that led to evolution in the ability to use positional notation of numbers. This was made possible by drawing on: 1) the potential offered by the coins microworld (which brought about the construction of additive numerical competence); 2) the potential offered by network communication (which allowed co-ordination between numerical activity using coins and verbal writing of the number); 3) the potential offered by the abacus microworld (which made it possible to overcome contradictions deriving from improper use of positional notation based on additive rules - e.g. writing 100010 to indicate one thousand and ten).

The following example reveals how the communication environment was used to assist co-ordination between written verbal language and representation with coins in the development of the concept of monetary equivalence.

<u>Example of a learning situation</u>

During experimentation with ARI-LAB, the students were presented the following game:
The teacher chooses a given amount and tells all the students. Each student generates coins to make up that amount, then, by means of the communication environment, has to send to the student with whom s/he is connected a message indicating the amount obtained and the coins used to form it (e.g. one 1000 lire note; three 100 lire coins, etc.). The interlocutor has to check that the solution received is correct and then make up the same amount in a different way. This solution is then sent back to the first student as before, and so on until one of the two students makes an error or is unable to find a new combination of coins. The rule is that it is not possible to propose previously used representations. If one of the students' representations is wrong (with respect to the given amount), and the interlocutor identifies the error, the latter wins the game.

The following excerpt is from a record of a real-time computer-mediated dialogue between two children (the amount to make up is 1450 lire):

....
MARCELLO-P -> 11 two hundred lire coins .... a one-hundred lire coin....a fifty lire coin
ALESSANDRA-L -> That is wrong
MARCELLO-P -> Why it is wrong?
ALESSANDRA-L -> because 11 two-hundred lire coins make two thousand lire ....
a hundred lire coin makes two-thousand one-hundred .... a fifty lire coin makes two-thousand one-hundred and fifty<
MARCELLO-P -> no! ....I tricked you with 11 two-hundred lire coins ...they make two hundred and fifty
MARCELLO-P -> I am wrong!..... they make two-thousand two-hundred.
....

The game develops by means of the written dialogue between the two interlocutors.
The features of the system make it possible to build a game structure that is appropriate for pursuing the previously mentioned learning objective. The game structure has been designed in order to foster co-ordination between representation of the given amount by means of coins (in the microworld), its verbal representation together with coin representation (in the solution environment), and the indication in verbal form of the structural components of the number (in the communication environment). The game structure calls for the planning of representation strategies that are increasingly articulated and complex. In this aspect, the student can rely on the assistance given by the coins microworld. The game structure fosters the need for students to evaluate their own personal strategy as well as that of their interlocutor.
The system assists the development of this capability since students share the same solution resources. The communication context of the game motivates and assists co-ordination of this activity in both the production and strategy evaluation phases.

Social context of use level

Experimentation of the system was carried out along the following lines: 1) it was conducted in real classes during normal school hours; 2) each child worked at a computer and all of these computers were linked up in a network; 3) experimentation took place over the medium to long term (from a minimum of two hours a week for three months to a maximum of four years with one class); 4) it was carried out by the same researchers who designed the system; 5) the class teachers were present throughout and took an active part in the proceedings.

In this section we shall analyse the project by considering how the system contributed to the structuring of a social context of use that assists the student to acquire skills in arithmetic problem solving. Analysis of the support offered by software systems designed or used for educational purposes entails focusing on the way to assist students who are unable by themselves to exploit the possibilities of action offered by the computer, identifying goals pertinent to the task at hand and control the use of interface forms in task solution. Analysis of these aspects implies looking at learning not only as an individual construction developed during interaction with the computer but also as a social construction developed inside its context of use. Tharp (Tarp in & Gallimore, 1989) distinguishes five means of assisting student performance: modelling, contingency managing, feeding back, instructing, questioning and cognitive structuring. These means of assistance are essentially of a social nature and are aimed at providing students with those external aids and control instruments necessary for the solution process.

Our analysis regards the role that the ARI-LAB system can play in allowing the teacher to provide new forms of assistance more suited to student needs. During experimentation a number of different forms of assistance were created with the support of the ARI-LAB system. One of these is described below. The teacher can assist the student in problem solution by means of a dialogue that may develop from mediation of the system interface. Let us consider the following problem:

A bus ticket costs 1300 lire. Lucia buys a ticket to go to school and another ticket to go back home. She has 2750 Lire in her purse. How much money will Lucia have left over after she has bought the bus tickets?

We report an extract of a dialogue between the teacher and a student which we extracted from the observation protocols made during experimentation with the ARI-LAB system.

The dialogue mediated by the system assists the student in a way which can satisfy both the student's and the teacher's needs. In this case the student needs to consider the problem within a context he can grasp and control by him/herself. The teacher can meet this need through the setting of a scene that supports production of a pertinent solution. In the setting of this scene, the teacher can refer to the student's experience (buying) and to motor perceptive abilities (movement of coins).

"Marcello generates 2600 lire (two 1000 lire notes and six 100 lire coins) in the 'coins' microworld then copies the money into the solution environment and cancels it from the microworld. The same thing is done for the 2750 lire. Then he tries to answer the question. He says: "350". The teacher asks: "How did you obtain this result?". Marcello is unable to explain; the teacher asks him to use the microworld to show the process he has followed to obtain that answer. Marcello seems unable to reconstruct his strategy. The teacher suggests regenerating the 2750 lire , then asks Marcello to explain what the money obtained represents. Marcello has some difficult in answering.
The teacher asks him to move the money necessary to buy the bus tickets to a different zone of the microworld window. Marcello begins to generate more money for the tickets.
Then the teacher sets the following scene: "This is the money you have in your wallet (pointing to the money in the microworld). You want to buy the bus tickets. I am the shop-keeper. Put the money you have to give me for the tickets here" (pointing to an area on the screen).
At that moment Marcello says "Ah ah! I have to move the money!" He understands the strategy to be carried out and solves the problem."

This assistance has been possible because the teacher and the student share the same means of communication (forms of the interface, movement) and refer to common experience. The teacher can put questions and give instructions in a way that helps the student anticipate the action to perform (moving the coins needed for the tickets from the total amount of money possessed) and its meaning (seeing the coins as part of the total amount and as the cost of the tickets). In other words, the assistance offered by the teacher, through the mediation of the computer, fosters anticipation of a pertinent data representation and of the actions which it is necessary to perform in order to obtain that representation.

THE SECOND PROJECT

This project concerns the integration of application software in the algebra teaching/learning process. Mastering algebra in high school implies both being able to model a situation in algebraic terms, i.e. finding out and writing formulas representing the relations among the entities involved, and being able to manipulate expressions and relations by means of rules in order to achieve fixed aims. Mastering algebra is the result of the convergence and co-ordination of three skills: systemic thinking (Licon Khisty, 1997), command of different representation systems, ability to convert from one representation system to another.
What actually happens in high school is that algebra curriculum is reduced to manipulation of algebraic expressions and relations, as well as procedures for solving equations, inequalities and equation systems. This view of algebra is often a constraint that the school imposes upon itself through text books, rather than through the syllabus, and is extremely limited it terms of the overall discipline of mathematics. What's more, this narrow interpretation causes difficulties and low motivation levels in students. It can be explained by the fact that manipulation abilities are more easily taught in this way and evaluation of what the students have learned is more straightforward.

A project dealing with algebra teaching/learning can take two different directions, both of which take into account student motivation: a) accept the narrow interpretation and try to overcome the difficulties; b) propose the other way of approaching algebra, by building up-to-date learning paths and, obviously, tackling the students' hurdles and difficulties. Our project follows the latter path, integrating application software that embraces mathematics skills and knowledge at various levels, and which is widely available and used in non-educational settings.

We were able to made use of the hardware already present in the schools because in many cases this had not been chosen with a specific use in mind. We chose to use different software packages for different purposes (a spreadsheet, imperative programming languages, a CAS system) according to their nature and our aims, despite the co-ordination and complementation problems that this entailed. Even though we did not have the means to act upon the software interfaces, we nonetheless assessed them in terms of simplicity, robustness, richness and usability, ensuring that they did not pose obstacles to the learning of new concepts.

In projects involving the integration of technology in the curriculum, it is important to define the mutual relationship between classroom and lab activity, two areas which can differ significantly (Auricchio et al,1994). Sometimes the teacher views the classroom and lab as separate modules; while students are taught mathematics in both settings, the activities performed are not explicitly connected. In some cases the teacher tries to connect classroom and lab activities, but gives greater importance to one of the two environments. In our project we consider the classroom and lab as environments of equal importance.

Epistemological level

Our project is designed to stimulate a more appropriate conception of mathematics in general and of algebra in particular. This may be a consequence of the way the teacher connects classroom and lab activities. Using the lab merely to support conjectures or to apply theorems already demonstrated in class leads students to think that new concepts can only arise in a theoretical framework. Vice versa, if new concepts and theorems are always introduced through heuristic work in the lab, and only later completed from a theoretical point of view, students may get the idea that all mathematical knowledge is the result of generalising particular cases and they may underestimate the importance and need for a theoretical approach to maths concepts. This is another reason why we consider classroom and lab as environments of equal importance.

A more appropriate conception of algebra may be achieved by using software to shed light on the following points:

- the meaning of modelling (not only algebraic modelling). When used for problem solving, spreadsheets force the user to identify the elements involved in a problem, their nominalisation (Arzarello et al, 1994) and initial modelling in a new representation system. The spreadsheet is also a good environment to introduce the concept of generalisation from a problem to a class of problems. Using an imperative program language environment does require the students to acquire modelling skills that must be developed outside the environment, but on the other hand it gives sufficient motivation for the effort involved. When a problem is modelled in algebraic language, the possibility of solving it automatically using a CAS (such as Derive) underlines the difference between high-level abilities (like modelling) and general procedures that can be automated. The CAS can also be used to focus on the mathematical concepts underlying general procedures (solving equations or equation systems); hence, students can be better guided towards awareness of different levels of mathematical knowledge.
- the actual importance of algebraic manipulation. A spreadsheet can be used, for example, for comparing functions. However, what can be deduced does not usually have the value of a proof, but only the value of a conjecture. It needs to be decided whether (and what) manipulation could be of any use. A CAS is able to perform any required manipulation that complies with the system's rules, but is not able to suggest the kind of manipulation suitable for giving an answer to a question.
- the distinction between mathematical operations on mathematical objects and calculation sequences. Using a CAS system highlights the fact that algebraic expressions and relations are objects (not mere sequences of calculation to perform) on which the system can operate according to the user's intention, providing this is correctly expressed in compliance with the system's rules.

Combining software packages of different nature can create an environment in which the following cognitive and metacognitive capabilities may be developed: 1) discussing the same mathematical concept from different points of view, which usually leads to a deeper understanding and better mastery of concepts (Duval, 1994; Schwarz and Dreyfus, 1995); 2) focusing on solution strategies rather than on performing calculations, which can improve problem-solving activities (Fey, 1989); 3) emphasising the meaning of maths concepts (Rothery, 1995) before being able to formally handle them; 4) converting a mathematical sentence from one representation system to another; 5) revealing what can be best approached using one software package or another; 6) fostering systemic thinking.

Finally, we note that curriculum modifications are not only influenced by the presence of hardware and software, but that this is a co-emergent phenomenon ("curriculum in action") arising out of the interaction between students, hardware and courseware, and between individual students, their classmates and teachers (Kieren, 1997).

Pedagogical level

In our project we consider the classroom and lab as equally important environments, because in both settings teachers can carry out the same kind of activities: directive activities, autonomous problem solving, and comparison of ideas through group discussion aimed at building shared knowledge.

Two considerations about the ways students can acquire new knowledge form the basis for our structure of class-and-lab activities: a) integrating application software packages results in a strong focus on representations and manipulation of representations; and b) visual perception and interpretation of software output play a central role in the construction of students' knowledge.

Extensive practice in representation manipulation results in a new mode of thinking. Tall (Tall, 1994) classifies the modes of mental representation of mathematical objects and the activities carried out with these objects. The most rudimentary is the "enactive sensori-motor mode": this begins with perceiving objects in the external world and acting upon them; objects can be handled and demonstration made by means of direct physical experimentation. The other is "iconic visuo-spatial mode", in which three different modes can be distinguished (symbolic-verbal, proceptual, symbolic-logical). The new mode of thinking is similar to the enactive sensori-motor mode, but instead of objects being real only in the form of physical entities (to be handled physically), they become virtually real (Chiesa, C. & Tarrago, F., 1997).

As concerns the role of visual perception, it is important to recognise that it is not pure perception that makes artificial mathematical worlds meaningful to the students, but the interpretation of the perceived images in terms of mathematical structures or relationships (Dreyfus via Balacheff, 1997).

Often, the answers provided by the software in use are not cut and dried but require interpretation. This helps to develop high-level intellectual abilities that are rarely attained within conventional schooling, e.g. approaching and understanding the thoughts of others. It involves thinking up functioning rules and constructing reasoning in line with those rules, sometimes following one's own way of thinking and sometimes detaching oneself from that mode.

In our project, lab-and-class activities are structured in such a way as to exploit different modes for acquiring knowledge whose effectiveness can be emphasised by the interactive environments used. For example, drawing on the possibility that spreadsheets offer for creating large numerical tables, we are able to:

- guide abstraction of critical algebra concepts (variable, unknown, parameter) through search/discovery of similarities and differences between groups of constructed expressions;
- analyse the differences between conjecturing and demonstration through a series of progressively focused attempts;
- reveal the need for and strength of formal instruments as compared to the limitations of proceeding by numerical attempts.

The need to consider worksheet layout provides the opportunity to develop systemic thought activities and modelling skills through thinking and acting by analogy. Being able to act upon the same mathematical object (e.g. an equation or group of equations) in a variety of environments leads to greater understanding of the object itself, and is used for developing skills in the conversion from one representation system to another.

Social context of use level

Analysis of the context of use mainly centres on the roles played by those involved and on work organisation. In our case, those involved are researchers, teachers and students, who interact within a discipline (mathematics/algebra) using software tools. The school concerned was a fine arts lyceum; while the type of school in which the system is used may affect the tasks that are assigned to the students, it does not bring about significant changes in the general philosophy of the project.

The students are set problem situations and, as they tackle these, are guided towards acquisition of new knowledge. As they proceed, they are called upon to give progressively more detailed explanation of their thoughts on the activity being undertaken. They work individually or in pairs, as well as taking part in group discussion guided by the teacher aimed at clarifying basic concepts or shedding light on the know-how they are building.

Teachers need to be familiar with some software applications and willing to explore their educational potential. Overall control of the class is left in their hands and they are required to participate in the analysis (led by the researchers) of the software's impact at the epistemological and pedagogical levels. The activities are planned jointly by the researchers and the teachers.

The researchers provide support in the classroom and in the lab, intervening where agreed and offering suggestions. They provide the learning material agreed upon with the teachers and collect data for evaluation and documentation of the project. In other words, they provide a bridge between the world of educational research and the school.

Overall organisation of the work is based on a number of observations (Auricchio et al,1994): 1) working together in small groups has the advantage of compelling students to share and compare their thoughts; 2) working together raises the attention level; 3) working well with a classmate is not always immediate, but is a skill that needs to be acquired; 4) individual work leads each student to tackle problems by him/herself, and this gives the individual a measure of his/her abilities and limits; 5) from the point of view of teaching, it is usually easier to control group work than individual work, since the number of resulting strategies to analyse is smaller, but in this way it may be that no interesting approaches or considerations emerge; 6) the problems that students face not only depend on the discipline but also on how it can be handled in the software environment; 7) opportunities for discussing side-issues arise more frequently in the lab than in the classroom, hence it is easier to lose track of the lesson; 6) group work can make it harder to evaluate each student's performance, and in the lab this problem also applies to individual work.

THE THIRD PROJECT

This study comes within the Qualification 2000 project, part of the EC's Adapt programme, and investigates the possibilities offered by integrating multimedia software and communication tools in order to produce flexible forms of training. These should be adaptable to different contexts and allow the acquisition within a single context of specific knowledge and skills as well as more general abilities.

In this respect, we observe that experiences regarding the use of multimedia and net-based systems for training mainly involve large organisations or universities (D'Halluin et al. 1996, Fulmer 1996, Neild 1997, The Open University 1996). The results of these are quite promising and indicate the possibility of giving impulse to continuous learning. (Blandow & Dyrenfurth 1994 Kaye 1991, Verdejo & Davies 1997, Wild 1996). Consequently, as already noted (European Commission 1993), it seems worthwhile to explore the feasibility of extending these kinds of training models to SMEs, which constitute the core of the Italian economy.

In this light, we have developed a model of continuous training that integrates face-to-face lessons, self-training and distance learning. For the self-training aspect, we have designed and implemented five multimedia packages on the following topics: graphic user interfaces, word processing, spreadsheets, databases and electronic mail. As to distance learning, we have created a communication environment that can be accessed from within the packages.

Epistemological level

We note that as a result of the increased complexity and competitiveness of the global marketplace, companies require personnel capable of meeting the demands of the moment and tackling problems that are inherently ambiguous, unstructured and complicated (European Commission, 1995). This calls for employees to be involved in problem solving activities and high-level thinking activities. Consequently, the learning of office automation concepts must be oriented towards the promotion and development of active knowledge construction among staff members.

In this light, when selecting the contents of the packages we took into account two needs:

- to give participants the kind of general knowledge that will help them gain awareness of technological evolution and its impact on the socio-economic situation;
- to provide tools and practical knowledge that allow participants to integrate new skills with those already mastered, so that they will be able to manage transformation in the workplace brought about by the introduction of advanced information technology.

Moreover, content has been designed to fit in with the actual setting where it is to be applied by using a design and problem-solving approach. Notably:

- topics are introduced in the form of problem-solving tasks; these lead to the identification of practical and conceptual tools which can be used to solve the task via sequential abstraction. This helps to develop thinking skills and promote active and responsible participation on the part of those involved.
- attention is centred on the conceptual aspects of a particular topic, presenting specific applications as practical examples of this conceptualisation. This makes acceptance easier and facilitates the autonomous transfer of skills acquired in one application to another.
- a strategic approach to all tasks, including routine ones, is encouraged by placing stress on the decision-making process and giving practical examples of how technology can support this process. This helps to increase motivation, as well as to promote awareness of the new technology and a confident approach to it.

To this end, the packages are provided with an interface which uses metaphors taken from the working context, offers realistic settings, proposes open-ended problems, provides the opportunity to observe computer-based case simulation, allows exploration of a situation and modification of its parameters, as well as providing a safe learning environment. In addition, the interface provides the possibility to approach topics from different perspectives. In particular, given a problem concerning the study of a computer tool applied to a specific task, it is possible both to focus on the computing concepts involved and to carry out the task for later in-depth analysis (Forcheri et al, 1997.

Pedagogical level

The pedagogical decisions underlying project implementation are based on a series of interviews providing cognitive analysis of learning difficulties, personal problems, and attitudes towards office automation and training in its use.

The outcome of these interviews revealed a generally positive attitude towards automation, especially among younger employees and those in very small companies. These people demonstrated a high level of interest, motivation to learn, awareness of possible improvements in work organisation deriving from automation, and viewed computer technology as a means for personal improvement. From a practical point of view, however, the interviewees seemed to be worried about a number of aspects: the need to devote leisure time to study; the risk of being unable to deal with the computer; having their performance measured against that of other employees, and losing autonomy.

Moreover, we noted that almost everyone is aware of the need for training in automation, but there is doubt about whether the kind of training activity undertaken will actually help to introduce quality automation in enterprises. This scepticism is mainly the result of previous training activities. Almost all the interviewees pointed out the following flaws in previous training experiences: the features of application tools were often introduced from a technical point of view without practical examples taken from the work context; there was a lack of synchronisation between the training content and the possibility of applying the content on the job; initial training was not followed by a phase of tutoring on the job. From a psychological point of view, moreover, the interviewees expressed fear of losing their reputation among colleagues and subordinates, and concern about the gap between learning needs and the teaching approach to the content. Finally, the need to devote their leisure time to study and exercises, and the problem of being loaded down with work during the training period contribute to create a sceptical attitude towards training.

Our continuous training model represents a response to the difficulties that were highlighted in the interviews. The combination of multimedia and network tools has allowed us to produce an affordable teaching-learning system that fosters self-training and at the same time offers the possibility to gain access to an expert or colleague whenever deemed necessary. Furthermore, it takes account of the personal attitude of employees towards the machine and their relationship problems with colleagues, helps employees to develop autonomy and initiative, and to acquire the capability of interacting and co-operating with colleagues, as well as reducing time problems.

We note that at first glance self-learning appears to be the ideal solution for continuous training in SMEs (Verdejo & Davies 1997, Wild 1996) because it takes production needs into account. However, it can only be a partial answer to effective training, as it requires a high level of motivation. Moreover, studying a topic, especially a new one, often requires discussion with colleagues and experts, further explanation, and so on. Finally, the lack of a guide can disorientate the trainee, discouraging further study and increasing psychological difficulties. The choice of integrating tools oriented to self-training with a communication system seems an appropriate response to these needs, as trainees are given the possibility to discuss the knowledge they have autonomously acquired with colleagues and with the trainer.

In our communication system, trainees are given the possibility of establishing personal relationships with the trainer (one-to-one message exchange, possibility for the trainee to ask questions privately, etc.), the opportunity to share with colleagues and the trainer the problems arising in individual and group activities; and the chance to communicate with colleagues in order to carry out collaborative activities (problems, exercises, discussions). These possibilities have been designed to increase flexibility in working strategies, promote innovative work methods, stimulate learning, and develop comparative skills and constructive communication with the outside world that will encourage creativity.

Social context of use level

First of all, we must point out that in company training evaluation of results is done outside the learning system and can only be carried out in the medium term. This evaluation is performed by the company itself and concerns the changes in working activities following the training period. Therefore, analysis of the context of use calls for careful study of the needs and expectations that the company has in respect to training. In this way training programmes can be drawn up which, beginning from the pedagogical problems faced by the users, helps them to acquire the skills needed for constructive and profitable involvement in the company's activities.

In an effort to understand corporate situations and requirements, we carried out a survey of employers based on interviews. These were aimed at gathering information about technological equipment, content to be learnt and the skills to be acquired by the employees through training. The interviews yielded the following results. As to automation, we observed that in the majority of cases neither local nor external networks are commonly used, even in sectors such as foreign trade where they can give a notable impulse. As to training in new technology, almost all the enterprises had tried out some kind of training (mainly traditional courses and tutoring) but, in general, these courses did not help people to develop autonomy and initiative, nor to acquire the capability of interacting and co-operating with colleagues - skills that the employers considered fundamental. CBT is hardly used at all.

Moreover, it was observed that to be effective, training in new technology should aim to make people aware of the potential of technological innovation in their job. Employers, especially in small enterprises, are aware of the potential of new technology but lack the knowledge needed to introduce automation effectively and efficiently. Finally, the main difficulty is to motivate employees to train.

The integration of multimedia and net-based facilities can help to meet these needs. In order to analyse this possibility, we organised a series of activities aimed at fostering simultaneously the learning of the computing contents, together with development of skills in group work and use of the network for sharing information and knowledge. For example, after assessment of individual and group learning, a group discussion is held about the work done, along the following lines. Asynchronous communication between trainer and trainee can be used to exchange assignments and feedback (directed to both individuals and groups). The trainer, after receiving solutions from trainees, sends back specific corrections and comments to the senders, and puts on a discussion list the solution and a list of most frequent errors organised by type, together with a brief explanation, general comments and questions. The trainees, in turn, have to put on the list their feelings on the trainer's proposal, answer the questions, take notes, etc. The trainer intervenes to solicit participation, to moderate the discussion and to conclude it. An example of the kind of task the trainees are asked to tackle is shown in *Table 1.*

Solve the problem:
Send a letter containing the detailed estimate of enterprise X to all shareholders. Personalise the letter and prepare the envelopes.
Send me back the following:
1. Normalisation of the problem according to the scheme: data, transformation, results.
2. Name of the software application(s) you intend to use in the different steps of the transformation.
3. Database of shareholders (a minimum of 9 records).
4. Detailed estimate (a minimum of 10 items).
5. Scheme of the letter (about 50 words).
6. Sequence of operations you performed, indicating, for each software application, the sequence of commands.
7. Two of the letters you prepared.

Table 1. Example of problem

Asynchronous communication can also be used to carry out collaborative activities involving two trainees or two groups of trainees. The following is an example of such an exercise: Trainee 1 receives a file formatted in Microsoft Word. Then, he sends Trainee 2 the corresponding text-only file (unformatted) and written instructions on how to obtain the formatted form. Trainee 2 has to send back the result to Trainee 1. They then discuss the differences between the two versions, if any.

Moreover, co-operative work among participants can be stimulated through discussion lists devoted to reviewing topics introduced in the course. A trainee is required to prepare a summary of a topic and to put it on the list. The other trainees intervene by suggesting modifications, making observations, etc. The trainer does not intervene in the discussion until s/he decides to conclude it.

Finally, it should be noted that this kind of activity gives trainees practical experience in network applications, and they are encouraged to use the net as a source of information and as a means to exchange knowledge, to hold discussion, and to work.

DISCUSSION POINTS

The choice of three levels of analysis (epistemological level, pedagogical level, and context of use level) appears to be appropriate in that it allows us to account for the various levels of mediation that the computer can apply in the educational environment.

In the following, for each analysis level we indicate a number of significant aspects, that emerge from the three projects; these aspects can be adopted as basic elements to consider in the design and reporting of research projects, in that they seems to be common to different projects.

Epistemological Level

- Nature and characteristics of knowledge adopted as a reference;
- Nature of the difficulties and obstacles involved in learning the knowledge at hand;

- Characteristics of the meanings that can be associated to concepts to be learned with the mediation of given systems;
- Type of approach to knowledge that is conveyed by the systems (a new form of enactive sensori-motor, perceptual-motor, symbolic-reconstructive);
- Characteristics of the available forms of interaction with a system's interface, in relation to the meanings that are to be conveyed;
- Nature and role of the representation systems made available through the interface, in relation to the kind of knowledge to be learned and the characteristics of the users involved.

Pedagogical Level

- Nature and characteristics of the form of activities that can be designed with the mediation of given systems; characteristics of overall work organisation;
- Characteristics of the individual tasks that can be designed and delivered making use of the functional characteristics of given systems;
- Mode of learning involved in carrying out tasks, in relation to the type of mediation that a system offers (learning by discovery, by imitation, by analogy, by trial and error, etc.);
- Characteristics of the learning contract brought about through system mediation.

Social context of use level

- Nature and characteristics of the computer-mediated interaction that develops between users, and their importance to learning;
- Characteristics of the roles and co-operation that develop between the actors in the teaching/learning process with the mediation of the computer;
- Nature and characteristics of the computer-mediated assistance that can be offered to learners;
- Forms of feedback (for the teacher and the student) that can be activated.

We note that the results of a research project should also consider analysis of the project's transferability to everyday classroom activity.

New regulations recently introduced in Italy providing for educational autonomy allow schools considerable freedom in deciding significant educational and organisational matters (the possibility to shift from largely subject-based teaching to a module-based approach, to introduce flexibility in the organisation of school hours and teaching, etc.). Moreover, the Ministry of Education's plan for educational technology provides substantial funding for information and communication technology projects developed for individual schools. In this context, the foundations exist for studying the conditions which may guarantee effective use of computers in ordinary teaching practice, not just at local level but on a wider scale.

In the light of our experience, we believe that this type of study (based on the analysis reported here) needs to take account of three types of constraint: constraints related to the knowledge to impart, constraints related to the professional skills required to manage the project in the classroom, and organisational constraints. As emerges in our study, these three types of constraint are strictly related, in the sense that if one constraint is modified, this very often has an impact on all the others, as well as on the relationships between them.

The study calls for the direct involvement of those in the real context who have the task of deciding the changes to be made to the system of constraints, choices they need to make by re-examining their own experience in the light of indications that emerge from research. This involvement takes the form of a training process for the actors in the educational system and calls for clearer definition of the relationship between educational institutions, research, training and innovation.

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Formative evaluation: Can models help us to shape innovative programmes?

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Introduction

Programmes designed to … d Communication Technologies) related innovation to education are … of the eternal optimist. What other breed would persevere for so long and wo… …nue to evangelize on every occasion that technology delivers a new chapter when all the evidence is that the school community is, at best, somewhat hard of hearing? Progress towards the widespread effective and appropriate use of ICT in education has been slow and tortuous in every country that has attempted the voyage but despite this governments, and societies at large, retain their enthusiasm for large scale programmes designed to bring change to the classroom. In the UK alone the government has committed itself to a huge (£230m) project to train every teacher to use ICT before the year 2002 and is shortly to introduce some draconian ICT related requirements for institutions who train teachers. In the 1997 UK General Election the winning Labour Party saw fit to make plans for the connection of every school to the Internet a key manifesto pledge.

Despite the problems, there are (of course!) a number of more positive things to say. Thoughtful consideration of the failings of many large-scale programmes has provided key insights into the reasons why many of them have gone awry. Marshall (1994), for example, reviews a number of educational programmes in the United States and warns us of the critical, but rarely addressed, significance of cultural mismatch between programme goals and target institutions. At the institutional level Passey and Ridgway (1994) lift the lid on schools that have managed to innovate and in doing so highlight the range of issues that need to be addressed during institutional planning. Ridgway (1997)
and Mevarech (1997) illuminate a third dimension through their insights into ICT related change and the individual teacher.

Against this background, it seems reasonable to ask if we can use the insights that we have to create a formative evaluation framework that can be used to help shape effective and worthwhile programmes. To be of use such a framework needs to capture key concepts and variables and it also needs to provide a model of the interactions between them that is on the one hand accessible but on the other does not present a gross simplification that renders it trivial. The aim of this paper is to propose a model that fits these criteria.

The overall structure of the model

Taken as a whole, the literature on ICT related change suggests that there are six basic dimensions that need to be considered when assessing the likely consequences of an attempt to bring about change. These dimensions manifest themselves, in slightly differing forms, at the level of the individual, the institution and the educational system.

In generic terms the dimensions are:

	Dimension	Description
1	Attitude	The attitude towards the proposed innovation. This may be characterized as active/positive, passive/positive, passive/negative or active/negative. (Rhodes & Cox)
2	Culture	Cultural (and structural) responsiveness towards change in general. Is the accommodation of change a natural part of day to day life or is change invariably resisted?
3	Beliefs	What are the basic beliefs about the nature of teaching and learning? Are these basic beliefs consistent with, or in opposition to, those associated with the innovation?
4	Values	To what extent will attempts to succeed in terms defined by the innovation be counterproductive in terms of the value system that normally prevails?
5	Support	Is support available to enable technical problems and pedagogical challenges to be overcome? Is adequate time available for reflection and planning?
6	Resources	Are sufficient physical resources available to support the innovation as an embedded feature of day-to-day routine?

We shall now consider how this model applies at each of the three levels.

The individual level

Attitude

The general attitude that an individual teacher has in respect of a proposed innovation can broadly be categorized as active/positive, passive/positive, passive/negative or active/negative. Whilst it is difficult to do much about a single individual, it is important to assess the extent and strength of negative attitudes in the target group for they can easily doom a programme.

Culture

Many individual teachers structure their day-to-day work in ways that minimize the need to change. (Ridgway (1997:7) gives a wonderful example of just such a teacher!) Moving teachers whose habitual pattern of behavior is to do exactly the same as they did the day before is a very significant challenge. However, there are also some teachers for whom innovation and change is the cultural norm and so programmes which focus on them are far more likely to be successful.

Beliefs

Whilst they may not realise it, teachers' day-to-day actions are grounded in basic sets of beliefs about the nature of teaching and learning. It is frequently the case that these beliefs are in fundamental conflict with those who design innovation programmes. When this is the case, and the divergence is not addressed, there is virtually no chance of significant change occurring.

Values

Teachers are only too well aware of the criteria by which they are deemed to be either succeeding or failing. Almost invariably, the degree to which their pupils succeed in public examinations is a key measure in determining the value that is placed on a teacher and this, in turn, critically affects self-esteem. Innovation programmes which threaten to have a negative impact on the perceived value of a teacher's work are very unlikely to succeed.

Support

Teachers who are seeking to implement an innovation will invariably need support in a number of ways. They will, from time to time, need technical help and if this is not forthcoming things will grind to a rapid halt. They need pedagogical support and the opportunity to experiment and take risks. They also need time for personal reflection and action planning.

Resources

Teachers, like everyone else, only use resources on a day-to-day basis that are readily available. In the context of ICT it is becoming clear that "readily available" really means much easier access than is currently enjoyed in most schools. Without physical resources nothing will happen.

The institutional level

Attitude

At this level, the critical attitude is that of the Headteacher or Principal. There is a large body of research which indicates that the attitude of this individual towards an innovation is the single most important factor in determining its adoption. For this reason, it is imperative that designers of innovation programmes seek to win over this critical group.

Culture

The concept of "The Learning Organisation" is frequently used to describe the type of institution that will succeed in the future. Some institutions have cultures and structures which enable changes to take place and become assimilated as a matter of course. Others succeed in erecting barriers which prevent even minor changes from occurring. Very strong levers are needed to shift institutions that fall into this second category.

Beliefs

The way in which a school orders its curriculum belies an underlying set of institutionally held beliefs about the nature of teaching and learning. A school which expects pupils to stay in their classrooms at all times and to work, predominantly as individuals, from set books is hardly likely to provide a fertile environment for an innovation designed to foster open-ended group investigations.

Values

As with individual teachers, schools are acutely aware of the criteria by which they are judged in the wider community. Proposed innovations which threaten to have an adverse impact on measures that determine the value that is placed on a school are likely to be strongly resisted. In the UK, public examination results play a critical role in determining the value that placed on a school by the wider community.

Support

Institutions, like individuals, need support as they seek to embed an innovation into routine practice. Some of that support (technical, pedagogical and time for reflection) may be made available by redirecting available resources but this is not always the case. External support will often be needed, particularly if leaders in the institution are being asked to reconceptualise fundamental aspects of key activities.

Resources

Most school budgets are dominated by expenditure on salaries and, almost universally, those budgets are under extreme pressure. Against this background expensive innovations (of which ICT is a prime example) present a major challenge. Handled badly, there is considerable scope for a damaging backlash.

The educational system level

The situation at the system level is rather more complex because in involves education professionals at school district and national level, politicians at these levels and parents. Collectively, these groups determine the social environment in which schools operate and despite their disparateness their bearing on the six key dimensions is critical.

Attitude

Politicians, in particular, play a critical role in shaping public attitudes towards innovations and those attitudes play a critical role in setting agendas for schools and school districts. A key problem arises when politicians (in particular) seek to nurture positive attitudes towards ideas that are fundamentally in contradiction. This is a particular issue at the moment as politicians in many countries are seeking to create a "Back to basics" climate at the same time as they are urging schools to embrace the Internet as a tool to support exploratory learning. Confusing messages such as this are hardly likely to create an environment in which worthwhile change flourishes.

Culture

Educational systems create cultures and structures that can either encourage or stifle innovation. Systems that seek to exert a high degree of control and that take punitive action against innovation failure breed defensive organizations (i.e., schools) which are unlikely to take risks. In such a climate effective change is very unlikely.

Beliefs

Almost uniquely, education is bedeviled by the widespread notion that its central concerns (teaching and learning) are simple matters of common sense and that all that is required is that teachers perform to a historically tried and trusted formula. The consequences of this notion are profound because many innovative programmes are based on a core set of beliefs that are fundamentally at variance with those held by many politicians and much of society.

Values

The values that are used to make judgements about educational worth are generally determined at the system level. The impact of these values on innovation should not be underestimated. If educational systems seek to classify schools in terms of the performance of their pupils in standardised tests of basis skills they should not expect those same schools to openly embrace innovations which require them to focus their attention in other directions.

Support

Wider support structures generally need to be created at the system level. In particular, the production and dissemination of teaching materials is most effectively managed at this level.

Resources

The overall resource that is available to support an innovation is generally determined at the system level. Whilst individual schools can often set their own priorities particularly expensive innovations often require additional funds to be allocated. The cost of ICT resources and their short useful life makes this problem particularly significant.

Assessing the likelihood of programme success

We can combine the details for the three levels in a single grid and can make a broad assessment of each element as being either positive (✓), negative (×) or mixed (O) in respect of the innovation. This is illustrated below (with fictitious data).

Dimension	Individual	Institution	System
Attitude	O	O	✓
Culture	O	O	×
Beliefs	✓	✓	✓
Values	✓	✓	✓
Support	O	×	×
Resources	O	✓	✓

The grid shows quite graphically where an innovation is likely to falter and where particular attention will be needed in order to overcome significant barriers.

By way of an example, the grid below is a personal assessment of the UK government's proposed programme to train every teacher to use ICT in their teaching by the year 2002.

Dimension	Individual	Institution	System
Attitude	O	O	✓
Culture	O	O	×
Beliefs	O	O	×
Values	×	×	×
Support	×	×	O
Resources	××	×	O

It is clear from the table that whilst there is a clear positive attitude towards the proposed innovation at the system level (and this is what is driving the programme) there is still a good deal of ambivalence at the school and the individual level. Digging a little deeper, it would probably be fair to class most individuals and schools as either passive/positive or passive/negative towards the proposal. On a more positive note, most parents will be in favour of the programme and this will translate into some pressure on schools to respond positively.

When we consider cultural and structural responsiveness to change the message is again mixed. Some schools and individual teachers readily assimilate change but many do not and the system as a whole has many administrative mechanisms embedded in it which act to preserve the status quo. This innovation does not appear to have a mechanism built in to it that will address structural and cultural resistance.

Things start to get really tricky when we consider the issue of beliefs about the nature of teaching and learning. In other contexts the government is proclaiming the virtues of a focus on basic literacy and numeracy. This runs counter to the beliefs that it is supposedly espousing in this programme. Given this confusion, schools and individual teachers are likely to go for the option that is least challenging to their current position. In other words, they will, in general, direct their efforts at the basic numeracy and literacy programmes.

If the situation with beliefs is tricky then it is downright nasty when it comes to values. Schools in the UK are, to all intents and purposes, now routinely placed in league tables on the basis of public examination results. League position directly impacts on admission levels which in turn determine resource levels. So no one is going to be enthusiastic about commiting time and resources to an innovation that diverts attention from the key objective of raising exam results. The only way through this will be to ensure that ICT use in this programme focuses on raising exam scores. And we all know what that will mean!

Turning to issues of support things are a little better. Teachers will be given time to go on courses (though they will not be long enough to change deep routed teaching patterns) and there is a commitment to produce materials to support classroom activities. Sensibly, the Internet itself is seen as a significant vehicle for dissemination.

Resourcing presents another very significant challenge. The government has put a lot of effort into a scheme that will deliver a fixed-cost Internet connection to every school and that is very welcome. However, even a basic assessment of the scale of access to ICT in general and the Internet in particular shows that most teachers, once they have been through the training programme, will not have access to sufficient ICT resources on a day-to-day basis to enable them to embed the use of technology in normal practice.

This may seem like an unduly pessimistic assessment but it is entirely consistent with historical patterns of reaction to programmes designed to support innovation.

Discussion

The model presented in this paper has deliberately been kept simple. It would undoubtedly be possible to refine each of the six dimensions and to detail sub-dimensions whilst also producing a comprehensive explanation of the relationships between them. That approach would have the attraction of intellectual rigour but the evidence also seems to suggest that it would not be used. The reason for this is that humans, when faced with multi-variable complex decisions, eliminate most available data from their considerations and simply focus on the small number of variables that they can handle.

The generalised model proposed in this paper invites a qualitative assessment on eighteen dimensions. It is argued that this can be done quite readily and that the resulting matrix makes clear the areas where a proposed innovation is likely to face difficulties.

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Exploring Assessment

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> 'Not everything that counts can be counted
> and not everything that can be counted counts.'
>
> (attributed to Albert Einstein)

Introduction

For almost two decades educators have talked about the changes technology brings to the classroom experience. Teacher behavior in technology-equipped settings (Kennewell, 1997) and the difficulties teachers encounter when they attempt to initiate or improve their teaching when using technology (Watson, 1998) have been discussed. Similarly, the need for curriculum reform (van Weert, 1998) and school reorganization (RØsvik, 1998) have been discussed but scarcely any work has been devoted to a discussion of the assessment of students in technology-equipped settings.

The situation we find ourselves in today can be compared to the age of westward exploration from the continent of Europe to the Americas. The early voyages of the Viking and Celtic explorers provided tantalizing clues as to the location of the Americas and their potential worth to future explorers. But the data were fragmentary at best and may have seemed tangential to the views, needs and mores of the people at large.

Our neglect of assessment may also be due to the incremental and ad hoc way technology educators have approached curriculum and our unwillingness to address issues such as learning theory, and the implications of political, social and economic factors driving technology in schools. The result is that government ministers and business people (*Education Beat*, 1998) are setting the standards and procedures. The situation can be compared to an imaginary scenario. Anxious to open a new route to the East, government and business ignore Christopher Columbus's statements that he has collected and analyzed data and he can go East by going West. Instead, government and business decide that their priorities call for a 'traditional' route over the Urals, through Mongolia and on to China.

By the time of Columbus's voyage a constellation of forces — religious, economic, scientific — created a sense of urgency for westward exploration. The message of Christopher

Columbus's vision of and attainment of a new passage to the East (albeit by going West) is instructive for us — not that there aren't other paradigm shifts that would apply — because it shows us how a conjunction of questions provoke a paradigm shift.

For the past few decades we have been in the 'between paradigms' stage in educational technology. We have had tools but have not always considered the relation between the tools and the users; we have not considered the relation between our views of how learners will learn to use the tools and what outcomes we expect from those learners. We have moved rapidly through a series of 'must do' curricula — COBOL, BASIC, LOGO, keyboarding — and focused on what must be learned with little attention to why or how it can and should be learned.

The discussion that follows is not a comprehensive overview of assessment —with all the factors analyzed as Columbus did — but more like a preliminary foray conducted by his predecessors, Eric the Red and Brendan the Navigator, among others.

Assessment

Assessment (from the French 'assidere' meaning 'to sit beside') is the study of students' performance. Although measures of students' performance are often included as part of an evaluation, assessment is a topic worth discussing on its own merits. Traditional paper and pencil tests are one form of assessment but other types — portfolio assessment, non-traditional paper and pencil tasks, performance assessment and formal and informal interviews — are also used. A wide array of assessment materials is currently available for use as models (Broadfoot, 1993; Herman, Aschbacher and Winters, 1992; Smith, 1991; Stenmark, 1989 among others).

Typically, assessment is conducted to gather evidence about the success or failure of a curriculum (Herbert, 1984; Herbert and Marshall, 1981; Stallings, 1975) and to gather data on how well individual students or an entire class are achieving curriculum goals. Increasingly assessment data are used to evaluate teachers' performance.

Ideally, assessment is part of an overall plan for teaching a wide range of skills, content, and processes, and is conducted at the beginning of an instructional cycle to provide the teacher and student with information about the current status of students' knowledge. Teaching is then aimed at supporting students as they engage a wide range of learning tasks and then, at successive points throughout the instructional cycle, with assessments of various kinds occurring on an on-going basis. Assessment is conducted at the end of an instructional cycle to provide (a) information on what has been learned and (b) where to proceed.

But this process can be distorted, as Applebee points out:

> . . . many problems in instruction can be traced directly to conceptualizations of teaching that reduce it essentially to a process of diagnosing what students know, teaching the missing information, testing to see what they have learned and re-teaching — in a never-ending cycle . . ..
>
> Applebee, 1989, p. 221

Such uses of assessment turn it into an input-output form of book-keeping that doesn't serve the student and directs the teacher's attention from how to support the student moving forward — which should be one of the primary goals of teaching and learning.

Assessment is not value-neutral. In the first place assessment practices are determined by prevailing conditions. For example, Murphy and Moon, in their discussion of learning and assessment, say:

> 'Any attempt to analyze curriculum and assessment proposals or to evaluate practice must be conducted within a framework that takes account of the moral, social and political order adopted and the educational purposes defined. The selection of content and the definition of objectives for the curriculum and its assessment are also informed by epistemology and views of the learner and the learning process.'
>
> (Murphy and Moon, 1989, p. ix)

Political and economic impacts on assessment

Many of the Western democracies are moving to the right politically. Traditionally, a move to the right has called for less government spending and greater accountability. The impact of such policies on technology-based education have been analyzed by Marshall (1995) and Nicholson (1995). For purposes of accountability, paper-and-pencil tests are viewed as more appropriate than other types of assessment because they are assumed to be more rigorous and more 'scientific'. In point of fact, their 'scientific' value is questionable.

Many of the less developed countries are setting policies to catch up with the more developed countries' use of technology. A major component of planning is the direct delivery of instruction according to 'traditional' classroom models and the use of paper-and-pencil tests directly modeled on or imported from the more developed countries. For both the more and less developed countries the goal is the same — increase teacher/student productivity and use assessment measures deemed trustworthy in order to collect data on how well that productivity is being achieved. In both cases 'productivity' has been defined in Taylor terms — higher students outputs at lower costs per student. Callahan (1962; Marshall, 1993) have compelling discussions of why such views don't work in practice. But a growing trend toward technology-based school accountability (Visscher, 1998) continues to rely on the Taylor model.

Epistemological impacts on assessment

Assessment design, delivery and analysis is dependent on epistemology. The behaviorist view asks 'How much do students learn?' and 'How much more did one student learn than another?' Such questions are presumed to be answered by traditional paper-and-pencil tests. The constructivist asks, 'What strategies do students use to learn?' and 'How do students organize what they learn?' and 'Do students recognize the structural similarities in seemingly different questions?' Such a view of learning renders meaningless the 'yes/no' quantitative data provided by many assessment tools. But it also calls into question the Rousseau-based attitude that as long as students are engaged by a task they are learning. Maybe yes; maybe no. Crucial questions of what and how they are learning must be answered.

So when we discuss the assessment of students' learning we must consider the viewpoints that direct questioners. The viewpoints are mutually exclusive as we have pointed out before (Marshall, 1993) and the importance of the differences in questions, as Benzie (1995) pointed out, must not be dismissed as minor skirmishes unimportant to the larger issue of what to teach and how to measure students.

Assessment and the Curriculum

If assessments are not value neutral, then the uses to which assessment instruments are put are also not value neutral although many psychometricians will argue that since the instruments are 'scientifically' constructed they are value neutral. Such arguments confuse the methods of assuring the validity and reliability of the tests — the psychometrician's work — with the content of the instruments and the types of instruments chosen. Politicians will gloss over these important distinctions, dismissing them as part of the educators' family quarrel, all the while choosing the type of instrument that best fits their need.

Although many curriculum builders do not consider assessment to be part of the curriculum development process, it is and will be — either by intent or by default. Let's say we want our curriculum to foster problem solving. It should make sense to present problem solving tasks to students — both to measure their problem solving ability and to assess the efficacy of the curriculum in promoting solving. In that case, the problem of assessment — both formative and summative — is a matter for inclusion in curriculum development plans. By default many assessments of students participating in problem-solving oriented curricula use 'traditional' assessment tools that bear little relation to the goals of the curriculum. The result often leads to a mismatch between curriculum goals and assessment outcomes — an outcome that has compromised the acceptance of many innovative curriculum projects (Marshall, 1994). But the clever use of assessment tools can also be used to torpedo a curriculum.

The situation can be described as follows:

Type of assessment	Learn from the assessment data and improve the curriculum	Use the data to show the curriculum is not achieving a set of goals
Directly related to curriculum goals	Yes	Questionable
Directly related to a different set of goals	Questionable	Questionable

Given a set of conditions that might call a halt to innovations not in favor, decision makers will opt for the 'directly related to a different set of goals' option in the belief that the data will not be examined but the results can be used to discredit the innovation.

But even when we take into account those issues we have still not moved very far along. We must consider the specific arenas of instruction. For example, are we assessing:

- general problem solving as defined by Newell and Simon (1972);
- domain-specific knowledge (Rosch, 1973);
    - and, if so, declarative knowing (knowing that) or procedural knowledge (knowing how)?

But we must also ask:

- do we believe that knowledge is socially constructed? And, if so, what are the implications for assessment? For example, do we ask the entire group what it knows and (a) look for the group's mismatch between what is known and our conception of the task and/or (b) do we look for wide variance from the group's understanding on the part of individual students?
- do we believe that knowledge is culturally bound? And, if so, what are the implications for our choices of assessment tools and settings? If, as Alan Bishop (1989) says different cultures have different values and different 'products', then, at the least, all international studies tell us may be that differences in the culture lead to different types of task performance and the assessment tools only measure a single facet of the teaching/learning prism.
- do we believe that knowledge is historically fluid? If so, our assessment methods must reflect that fluidity in both content and process. For example, in the United States we are still testing students with the types of assessment instruments that were originally developed to select or reject recruits for the Great War — using instruments that provide a quick and cheap way to screen students on the 'how much do they know?' question. The history of testing in China (DuBois, 1967) is instructive. As political, social and economic conditions in China changed so did the design of the tests used to select civil servants. Now, at the dawning of the Information Age, similar changes should be anticipated in the design, delivery and assessment of instruction.

Assessment strategies

Paper-and-pencil tasks

One of the most widely used assessment tools in many countries is the 'fill in the blanks/multiple choice/true and false' method commonly used in standardized tests. In addition to the problem that such measures only tell us how closely students approximate what we think of as 100% performance and tell us little about how students know and how well they can apply what they know over a wide range of situation there is also the validity problem.

Although most tests based on the standardized test model are viewed as 'scientific' the reality is that they are prone to all sorts of distortions, as a result of problems in construction, which render them invalid. In testing, construct validity — measuring what you think you are measuring — is essential. But many (if not most) teacher-made tests contain ambiguous items which invalidate the score. Even measures ostensibly constructed by the pros contain threats to validity. Consider the problem of designing a valid analogy test. Analogy tests are very popular because the ability to solve analogies is thought to be an indicator of general intelligence — 'g' in Spearman's (1923) terms and independent of specific sets of aptitudes. In reviewing students' analogy test performance Goldstein (1962) was curious as to whether students' ability to solve different types of analogies — synonym, antonym, logical relations of time, causality, sequence, and superordination/subordination — followed a developmental progression. He pointed out that analogy tests current at that time failed to present equal numbers of items of each type so a study of the interaction between students' performance and item type was murky at best. He constructed an analogy test with an equal number of items of each type.

But there was a problem with Goldstein's test. Achenbach (1970) found that analogy test items could often be solved by the subjects supplying the most frequently occurring word response as the correct answer. Consider the item 'Man is to king as woman is to queen, throne, house, castle.' The correct answer 'queen' also happens to be the most frequently occurring response to 'king' in word association tests. So subjects could merely be supplying a 'clang' response to 'king' and not solving the analogy based on the structure of the item.

To test for the 'clang' as a solution strategy Achenbach designed his own test, The Children's Associative Responding Test, where half the items could be answered with word associations and half where the frequently occurring word association was the 'foil' or incorrect answer — 'Beggar is to rags as king is to . . .' and both 'queen' and 'robes' were among the choices. But Achenbach did not control for item type as Goldstein did so his results were compromised by the differences in difficulty level of the items.

Marshall (1981) constructed an analogy test utilizing the features of both Goldstein's and Achenbach's work. There were an equal number of item types and half the items had the frequently occurring word association response as the correct answer and half had that response as a 'foil.' Results showed a different developmental pattern from Goldstein's and a different pattern from Achenbach's on the foil and nonfoil items. So tests designed with all the scientific rigor available to psychometricians are invalid for one or more reasons. So much for the vaunted 'scientific' value of traditional paper and pencil measures. The merit of Goldstein's and Achenbach's tests, however, is that they provided a window into students' solution strategies — can they solve problems based on different types of cognitive operations and can they suppress word association responses?

Such issues focus on an important element of assessment — the overall validity — of our instruments. Validity has several faces: content validity asks how well or how much of the content and processes we expect students to know has been represented in our assessment; criterion validity asks how well our measures predict how the student will perform in the future; construct validity asks how well the measure assesses knowledge and performance of traits and skills. In discarding 'traditional' ways of assessing students it is important that we do not ignore fundamental questions associated with the art and science of testing. In preparing for his voyage West Columbus did not throw all the maps, charts and navigational tools overboard. Instead, he choose wisely which would help him accomplish his mission.

Interviews

But other types of assessment strategies may yield more interesting insights into students' thinking. Consider students' responses to a problem solving computation task presented by a software program. Interviews conducted with the students yielded many interesting insights in the ways (a) students solved the problems and (b) their overall facility with mathematical topics.

The software was specifically constructed by present students with several different sets of circumstances: (1) generate more than one answer to problems involving addition, subtraction, multiplication or division; (2) recognize that many of the problem could be solved without computation by recognizing the 'identity' (1 = 1) solution; and (3) recognize that some problems were impossible to solve given the numbers provided.

The cognitive demands of the tasks on the one hand and students' understanding (or lack of understanding) of the principles of computation and the relations among numbers on the other hand led students into difficulties that had little to do with whether or not the task was addition, subtraction or multiplication. All of the children selected by the teacher for the interviews had scored well on yearly administrations of standardized achievement tests — a case of 'putting the school's best foot forward' but all of the students seemed to have difficulty shifting from a 'typical' way to demonstrate their computation ability to the task at hand. Here's an example of how Julie, a second grader, (age 8) coped with the addition task:

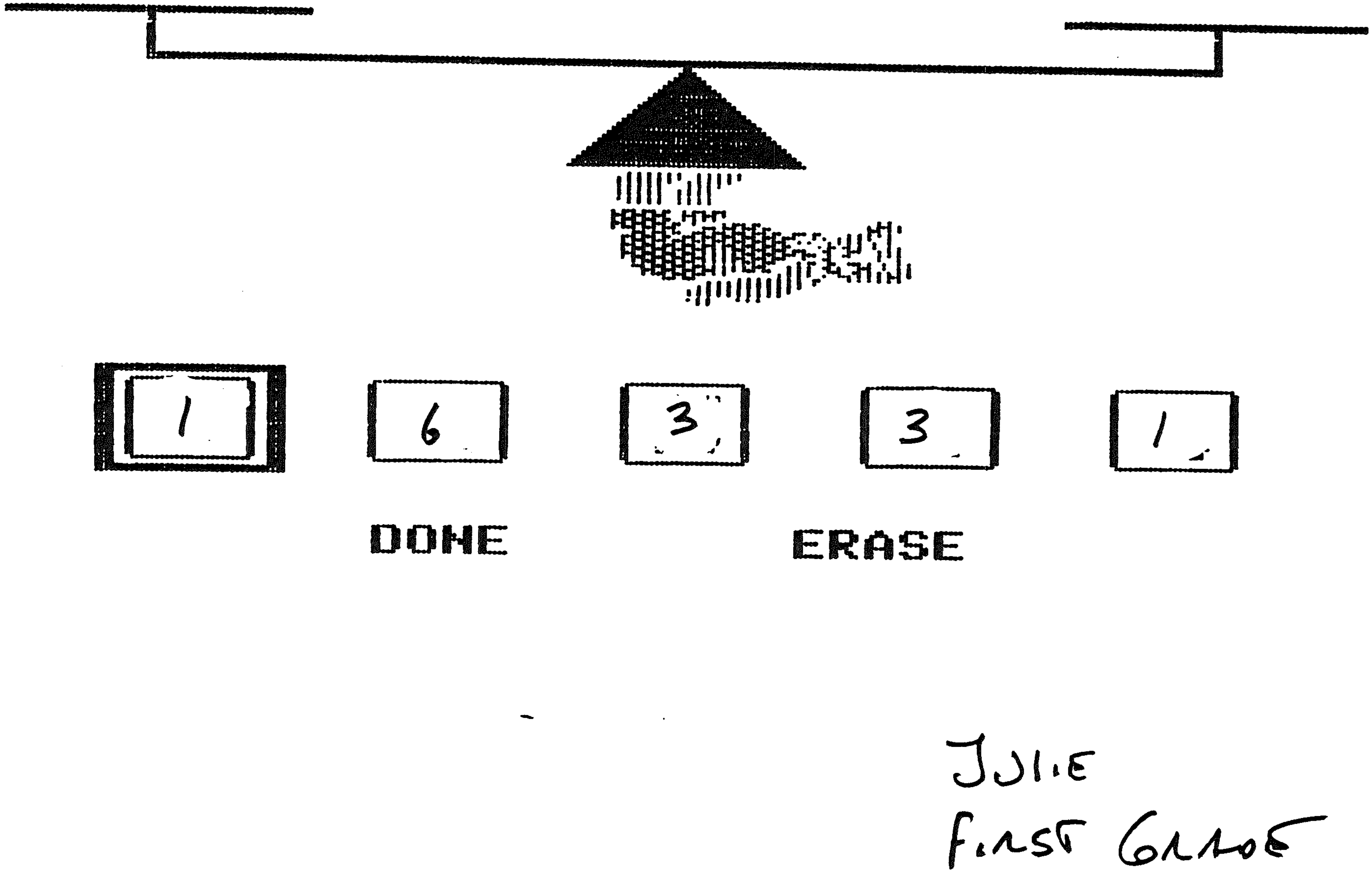

FIGURE 1

Julie: (Places 6 on one side of the beam and 3 and 3 on the other side of the beam.)

Interviewer: Is there another way?

Julie: (Places the 3 and 3 on the left side of the beam and the 6 on the right side of the Beam.)

Interviewer: Is there another way without using the 6?

Julie: (Places the 3 and the 3 on the left side again and places the 6 on the right side.)

(Marshall, in progress)

So with the addition task Julie was able to add correctly but she did not recognize the 'identity' solution 3 = 3 and 1 = 1. In fact, less than half of the students interviewed (from grades one through six) ever solved the problem with the identity solution. Their reasons echoed Mara's, who said, 'A number can't equal itself.' From this we can infer that Julie's understanding of math is essentially computationally bound — she sees problems in math in terms of adding, subtracting, multiplying or dividing and not in terms of the relations between numbers.

Direct observation

Often information can only be gathered from observations of students and interviews with students as they work with tasks. Questioning students about the strategies they use and don't use as they work can point out for the teachers aspects of the learning situation which need to be addressed as instruction proceeds. Many of the standardized tests currently available do not provide us with the depth of information that direct observations of students at work provides us. But we must be careful of the lens we use when conducting our assessment and avoid the pitfalls of a 'Clever Hans' variety where the interviewer's behavior cues the student as the correctness of behavior.

The computer can be an especially rich resource in this respect if the software is designed to allow us to see the choices students make thereby giving us insights into the status of children's thinking. At the very least the interviews might help teachers discover if students use trial and error, counting on fingers, the development of a primitive algorithm or the misapplication of a complex algorithm.

Direct observation also helps teachers assess the impact of personality factors. Is the student impulsive? If so, is that impulsivity due to a quick understanding (or misunderstanding) of the task and a desire to work through it quickly or is it due to an inability to focus on the task or a realization that they do not understand the task or do not have strategies for solving the task? I am currently working with teachers in a school where many of the students may have had fetal alcohol syndrome or where their home life is disorganized. The impulsivity of those students presents interesting challenges for the teaching/learning situation. In the context of the computer room, students are rarely satisfied with working through a segment of a piece of software. Instead, they move from one piece of software to another.

The data collected through interviews and observations can help us guide students toward the use of more effective strategies for their own learning and also help us develop software that enables us to work within a diagnostic framework in technology-equipped settings. Imagine, for example, if today's software had a 'capture' feature built in which allowed us, after students had solved a problem or several problems, to review the steps and think about the implications of those steps.

Student-generated work

We must also be cautious about using the work students generate themselves — a frequently used alternative assessment strategy — as the sole basis of our information gathering. It is not clear that looking at problems students generate themselves tells us what students *can't* do. Piaget's belief that we must examine children in 'disequilibrating' situations must be one of our assessment strategies. Nevertheless students' work can provide us with insights into their understanding of the task, which in many instances is sure to be very different from an adult's understanding of the task.

Reliability and rubrics

The use of interviews, direct observation, and student-generated work brings us to the issue of reliability and rubrics. Imagine a situation where a student writes an essay and receives the highest grade possible only to find that the next year the same skills and processes that were used are assigned the lowest grade. As schools use 'alternative assessment' strategies more is at stake than devising or selecting tasks. All —students, teachers and administrators — must work together to ensure that there is agreement on what criteria will be used in assessing the work — the development and application of rubrics — and that there is general agreement on how those rubrics will be applied to each student's work. The question of face validity — do the students value the work that is to be produced and deem it important in their overall educational development? — is extremely important. If the students don't perceive the work produced as part of an 'alternative assessment' strategy important then the process loses its value.

The role of context in the development and interpretation of measures

The role of context is an important but neglected factor in the assessment of students. Julie had high scores on standardized achievement tests, which signaled to the teacher that she had 'mastered' addition. Our question was whether or not she had acquired a sufficiently complex understanding of addition to use those skills successfully in a wide range of circumstances. Interviews in conjunction with the novel application of number skills showed that Julie's math knowledge was limited to traditional settings. So the context in which the task is situated is important.

Here the work of P. N. Johnson-Laird and P.C. Wason (1977) is instructive. Wason devised the famous 'four card' task to investigate subjects choosing conditions which would allow a valid inference to be made. Subjects, all of whom were adults, were presented with four cards which have a letter on one side and a number on the other side. They are given a rule: 'If a card has a vowel on one side, then it has an even number on the other side.' The task is for subjects to state which card or cards must be turned over to find if the rule is true or false. The researchers found that the most frequent answers were 'A and 4' and 'only A' — both of which are incorrect. At this point we may say, 'But what does the four card task have to do with assessing students' performance in technology-equipped classrooms?' The sequel to the research tells the rest of the story and provides us with the need to consider designing and applying our assessment tools over a wide range of contexts. Johnson-Laird, Legrenzi and Sonino Legrenzi (1972) devised a task with the same structure but a different context. Their subjects were asked to imagine they were postal workers who must decide if the rule 'If a letter is sealed, then it has a 5d stamp on it.' Four envelopes were shown — the back of a sealed envelope. the front of an envelope with a 5d stamp, the front of an envelope with a 4d stamp and an unsealed envelope. With the envelope task 22 of 24 subjects were correct while only 7 of the 24 correctly solved the original four card task.

The variable nature of human performance, as demonstrated by the subjects' performance on the four card task in different contexts, tells us that we must provide a wide range of situations in which to conduct our assessment activities. The same skills should be assessed in many different situations. If we anticipate lifelong learning or 'schools without walls' as a future development, we must face the fact that we cannot be sure that our students, whether of elementary school age or adults working in technology-based settings, generalize the deep structure of software or tasks associated with their school work or daily work across many different situations. For example, many adults, when confronted with a spreadsheet or database program that looks different from the one they have been trained to use, state that they cannot use that software and become confused in trying to enter and manipulate data.

Observations of their attempts to work with the software show that they try 'trial and error' procedures or call upon the teacher/trainer as each new step must be taken. The 'context' of the new software, its 'look and feel', presents them with challenges that they feel they are unable to meet given their understanding of the prototype of spreadsheet use they developed when they learned to use their first spreadsheet. Their frustration may signal that they never really learned 'spreadsheets' and that they learned *Lotus 1-2-3* or *Excel* as a routinized set of keystrokes. As technology educators we should want to know more about what our students, of whatever age, know about the tools they are using.

The Problem of Analysis

An important issue is whether or not to jettison the statistical methods and research methods developed over the last century. Appropriately used, the Pearson Product Moment Correlation or multiple regression analysis is as useful as a day's worth of classroom observations because, if properly used, the data can help us look at the situation systematically. All methods, when used appropriately, can be powerful ways to answer questions. The problem heretofore has been that statistical and research tools have often been applied inappropriately. Either only statistical tools have been used and in situations where observational and interview data may have better been collected first or the tools used failed to fit the questions asked. The Rousseaian approach that students should freely engage the classroom and be judged on the basis of their apparent satisfaction with the scene can be as misleading as the use of a pre-/post-test analysis of standardized achievement test scores.

Conclusion

The above discussion took the long way round to establish several important points when constructing, choosing or using assessment tools. Many, many different factors must be considered:

- What are the social, political, economic and epistemological bounds of the situations? How many different types of assessment strategies must be chosen to satisfy multiple and competing constituencies? Who should make decisions about what types of assessment strategies are chosen and for what purposes the information will be used?
- How well-constructed are the tasks we present? The ingredients in the task itself are important for if one or more facets of the task (item type and 'clang' possibility, for example) aren't carefully combined the results of our assessment may be misleading.

Are the tasks abstract or concrete? What types of content and process are represented? Is the sampling of tasks representative of the types of knowledge and skills expected (a) within 'the academy' and (b) in 'the real world'?

- What is the level of development of the students? Do we know the types of tasks students and their peers can perform so we have a benchmark against which to measure performance. We can't assume a second grader can perform a task that fourth graders can't perform unless we know a lot more about the setting;

There is a continuum of tools — formal to informal assessments — and each tool has its place in our assessment program. Each might properly be used if we know the questions we are asking and how the assessment tool matches that question; if we recognize the limitations of the tools.

If we have avoided or neglected an examination of our tests and measures for use in technology-equipped settings up to this time, perhaps now, as we grow more confident about what we want to do with technology, we will also grow more confident about our explorations of assessment. As technology educators our roles call for:

- understanding how different viewpoints about learning translate into different questions to ask about that learning;
- reviewing and applying a wide range of strategies to describe children's learning;
- reviewing, acquiring, applying and/or designing tools for both on- and off-computer assessments;
- incorporating those strategies into the design and delivery of technology-based instruction;
- systematically reviewing the curricula as (a) technology moves forward, (b) as students' use of technology changes and (c) as society-in-general continues to define what is important. This situation is like a house of cards. Change one element and all others may fall down. The trick is retain the important while jettisoning the irrelevant. And the most difficult trick may be to decide what is relevant — from a social, political, economic *and* epistemological point of view.

The field of technology will change. Whether the course of cognitive development will change as a result of our use of technology is a question open to exploration. A host of questions — some rooted in the behaviorist tradition such as 'Does the child develop more rapidly when using technology?' and some rooted in the constructivist tradition such as 'What changes, if any, occur across what groups of students and under what conditions by what means?' — should be asked to enable us to help students learn through the use of technology. As a result of our questions. strategies and tools we should be able to chart the course of children's learning in technology-equipped settings much as Columbus and those who went before and those who followed were able to chart the earth and then the universe.

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GENOVA

Children's Participation in Evaluating: The Role of New Information Technologies in Schools

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Introduction

While children act as informants in many evaluation studies of the integration of new technologies into schooling, rarely if at all, are they accorded the status of stakeholders. In general their views, opinions, even learning preferences and goals provide a rich source of data for the evaluators but they do not participate in the negotiation of the focus, procedures and interpretations of the study itself. Generally only adults are identified as stakeholders, and most often they are restricted to policy and curriculum makers and teachers.

This omission is critical because in many ways today's children have appropriated the new technologies for themselves, in ways that have not happened with previous technologies, and in ways that adults have yet to fully appreciate. In some classrooms they are the experts, the decision makers and the teachers. They change what is happening at the individual level, and if they are listened to, they can help shape what happens at the classroom and school level as well. As well these children are the consequential stakeholders of the policies and practices in place before the evaluation and put in place as outcomes of the evaluation.

A number of other historical factors have also come together to make it critical to reflect on the role of children more generally in evaluation studies. These are the UN Convention on the Rights of Children, the emerging paradigm of childhood studies and the emerging discourse of children as a minority group.

This paper will present the background to each of these factors and explore what contribution each might make to the development of a form of evaluation which recognises children as participants in the design, processes and interpretations of evaluations relating to the use of new information technologies in schooling. As well a number of methodological issues which arise out of children as stakeholders and informants will be discussed. The intended outcome of these explorations is to engage researchers, evaluators and educators in reflecting on ways to improve current evaluation studies of new information technologies in school settings by including children as both stakeholders and informants.

UN Charter of Rights

In 1989 the United Nations General Assembly unanimously passed the Convention on the Rights of the Child. Since then 175 countries have ratified this agreement making it the most widely ratified human rights treaty in history. It is also unique in that it incorporated the full range of human rights: children's civil, political, economic, social and cultural rights. Basically the convention sets the minimum moral and legal standards for the protection of children's rights, defining a child as a human being under the age of 18 years. As well as the more well known stipulations relating to civil rights and freedoms, and special provisions in situations of armed conflict and exploitation the convention has four general principles:

- States shall ensure each child enjoys full rights without discrimination or distinctions of any kind;
- The child's best interests shall be a primary consideration in all actions concerning children whether undertaken by public or private social institutions, courts, administrative authorities or legislative bodies;
- Every child has an inherent right to life and State shall ensure, to the maximum extent possible, child survival and development; and
- Children have a right to be heard.

According to John (1996) this convention can be seen as a transcultural benchmark for a change of priorities in our professional relationships with children. She argues that the final principle, in particular, challenges both research and practitioner communities to seek ways to more fully involve children, to forge new partnerships with them and to ensure that they become agents in their own lives.

So far within various professions the response to this challenge has been patchy at best. In particular in education there are few examples of children's voices being heard in important ways. While there are schools which have successfully experimented with more democratic systems of decision making [#] and ethnographic studies which have used children as informants (Buckingham, 1993; Hirsch, 1992; Kubey & Larson, 1990; Mayall, 1994a; Solberg, 1996) there is little evidence anywhere that these challenges are being taken seriously in any systematic way. In general schools and school systems are highly autocratic with little evidence of democracy even among the adult community of teachers. As well few in the research and evaluation field have seriously involved children as decision makers

One of the many stumbling blocks to changing this situation and involving children more fully in the decision making processes associated with their own education is the way educators have historically constructed childhood as a time of immaturity. Such a view has led to concern, even suspicion, that data collected from children is 'contaminated' because it comes from children and to an almost universal denial of children's rights to be part of decision making processes.

The emerging field of childhood studies

While the immaturity of children is a biological fact, Prout and James (1990) argue that the ways in which this immaturity is understood and made meaningful is a fact of culture. It is in this sense that childhood as an cultural institution is socially constructed. Traditionally within education our constructions of childhood have been strongly based on developmental psychology. Within these constructions the child is seen as an immature and incomplete adult, as an adult in the making needing to be socialised into adult ways.

This overwhelming focus on immaturity almost excludes the notion of the 'whole' child as a social being who is knowledgeable about their worlds and lives (Frones, 1994; Mayall, 1994b; Prout & James, 1990; Qvortrup, Bardy, Sgritta & Wintersberger, 1994). John (1996) argues that traditional epistemologies have actually excluded the possibility that children could either be 'knowers' or agents of knowledge. Historically research and evaluation studies in education either represent children in the future voice as adults in preparation, in passive voice as recipients of adults' attention and treatment or as objects of structural determinations.

In response to these concerns a field of study, known as childhood studies, has emerged within a number of European research communities (Frones, 1994; Mayall, 1994b; Prout & James, 1990; Qvortrup, Bardy, Sgritta & Wintersberger, 1994). These groups have as their main foci increasing the voices of children in research for and about children and exploring theoretical frameworks which position children as active in the construction and determination of their own social lives, the lives around them and of the societies in which they live (James & Prout, 1990). While these researchers are mainly coming from sociological and social-anthropological traditions they have much in common with educational researchers who work in the area of social constructivism (Bereiter, 1994; Cobb, 1994). Both search for theories which explain the processes and mechanisms of the reflexive relationships between children as agents and 'acted upon'.

In education there seems to be particular resistances to these different ways of thinking about childhood. Prout and James (1990) argue that in education the traditional notions of development psychology and socialisation are so strongly entrenched that they have become what Foucault refers to as 'regimes of truth':

> .....these operate rather like self-fulfilling prophesies: ways of thinking about childhood fuse with institutionalised practices to produce self-conscious subjects (teachers, parents and children) who think (and feel) about themselves through the terms of those ways of thinking. The 'truth' about themselves and their situations is thus self-validating.
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Mayall's (1994a) research into health care of children at home and at school confirmed that children at school think about themselves in these terms. She found that children constructed separate identities for themselves as school children, seeing themselves at school as objects of socialisation. In contrast in the home, these same children saw themselves as participating members whose self-reliance and competences were valued. Mayall argued that children's ability to negotiate in different ways in these two settings was heavily dependent on the adult's conceptions of childhood. Even within the area of information technologies, where children are identified by adults as 'the computer generation' and their comfort and expertise is envied by many adults, children still have strongly identified positions relating to their sense of control of school's computing (Downes & Reddacliff, 1997). These positions of 'powerlessness' are in contrast to their positions in the home where they seen themselves as participants in the key decisions made within the family.

Children as a minority group

While it is not common to think of children in terms of a minority group, there is a valid argument that their lack of voice, participation and power, positions them along side other minority groups who are marginalised in society. John (1996) argues that we need to re-focus some of the concerns in research with other minority groups onto work with children. In this way we might begin to more clearly see ways of transforming traditional power relations between adults and children and of developing models of participation and empowerment. In many ways this approach clearly recognises the political processes needed to be undertaken both within and without the community of children if participation and empowerment are to occur.

Drawing on the work of Steve Biko, John (1996) alerts us to three prerequisites to the growth of a political movement amongst children. These are responsibility, unity and a people's movement. Responsibility refers to self- responsibility for educating members of the group about their status and the collective nature of their oppression; unity involves identification with other children and presenting a unified voice to the outside world; and a people's movement refers to turning outwards towards societal responsibilities. John believes that these political processes form a basis for building a bridge between the world of children and adult society. She rejects the notion that adults can /should bestow rights on children who passively receive them. Her 'bridge building' model involves a political process, as described above, and creative alliances between children and adults where children are heard and understood.

From research activity with and for minority groups John (1996) also draws attention to the notion that 'voicing' is not just about hearing what the minority group have to say and advocating on their behalf, but about changing the power relationship between the researcher and the researched such that children are enabled to be active in voicing their own concerns. This shifts the role of the researcher somewhat more towards that of an agent of social change. Such a shift brings a host of ethical and methodological issues to the fore. John admits that at this stage little research has been undertaken with and for children within this framework so few of these issues have really been explored. She argues that, at present, the key commitment is to:

> ".....work with children in this way....we have to learn to look at the world with their eyes and hear their own articulations of their experiences and, importantly, communicate with them."
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> P. 22

Such a commitment, particularly when considering evaluation studies in school settings takes as given that adults recognise the right of children to be heard and understood, and that children can make a unique and valuable contribution to the evaluation.

Models of Evaluation

Of all the various models of evaluation that have been put forward and used in educational settings Guba and Lincoln's (1989) *fourth generation evaluations* seems to provide a model which could most readily allow children's authentic participation in the evaluation process.

In this model evaluation activities involve constant negotiation and re-negotiation with relevant stakeholders. As well the method is consistent with the paradigm of constructivist inquiry. McEvoy and Rissel (1992) when evaluating the appropriateness of this model for use with Aboriginal Health Programme's highlight the role of the evaluator as a mediator who facilitates negotiation amongst stakeholders. They argue that such an approach fosters the empowerment of the participants and that accountability for the evaluation results and subsequent action are shared rather than assigned.

The following model is a slight adaptation of Guba and Lincoln's model (Guba & Lincoln, 1989) which also takes into account the process used by McEvoy and Rissel (1992) It has the following steps:

1. Initiate contract with client/sponsor / organise team, etc.
2. Identify the stakeholders.
3. Develop within-group joint constructions.
4. Enlarge Group constructions through new information and increased sophistication.
5. Re-focus on resolved and unresolved claims, concerns and issues.
6. Select data collection methodology, develop instruments for evaluation.
7. Organise data collection, analyse and interpret data.
8. Define and elucidate unresolved items and competing constructions, negotiate and jointly construct findings.
9. Distribute and use findings / recycle the process to take up any unresolved issues.

This model sees greater emphasis given to negotiation at both the early stages and in the constructing of findings. They argue that by using a process which they define as a ‘hermeneutic dialectic’ process (Guba & Lincoln, 1989), all stakeholders

> “are thus simultaneously educated (because they achieve new levels of information and sophistication) and empowered (because their initial constructions are given full consideration and because each individual has the opportunity to provide a critique to correct, to amend or to extend all the other parties’ constructions.”
>
> P. 149

While the tone of Guba and Lincoln’s writings suggest that they have only adult stakeholders in mind, their definition of stakeholders, as groups who have something at stake in the evaluand, would be inclusive of children, at least in the sense of children being consequential stakeholders. John (1996) would probably argue that the educative and empowering processes in this system would need to be extended to include the political process through which children may be empowered to authentically participate in the actual ‘hermeneutic dialectic’ process.

Issues

By involving children in such a model of evaluation two different but related roles exist for children. The first relates to the role as stakeholders the second as informants. Each of these has related ethical and methodological issues.

As Stakeholders

For children to be identified and engaged in this process as stakeholders, both researchers and other stakeholders must put aside their assumptions of superiority based on age and cognitive maturity. This is not to say that a differential does not exist, but that regardless of differences, all stakeholders are accorded the rights to participate fully in the negotiation processes.

The issues of power and status differential would still remain but it needs to be recognised that such differentials are not confined to those of children and adults. Differentials generated by race, class and gender abound in adult-adult studies. Mandell (1991) argues that once the adult assumption of superiority based on age and cognitive maturity is put aside, researchers (and evaluators) can build on the techniques that field workers long ago developed to reduce social distance based on other differentials.

Even when adapting such strategies the problem may still remain that the children have not traveled sufficiently far down the part of politicisation to think about themselves in ways that facilitate their participation. If children are practised in identifying themselves in ways teachers traditionally view them (Mayall, 1994a) they may find it difficult to move out of the 'object of socialisation' role, or the complainant role, where they can identify issues and problems but believe the 'power' to change things belongs with adults, (John, 1996) to a role in which they accept mutual responsibility for the needed action which emerges out of negotiations. How these issues unfold in evaluation studies is as yet unmapped because few if any evaluation studies in school settings, which use this or similar models of children's participation exist.

As informants

A number of issues arise out of children roles as informants. The common issues related to research for and with children include consent, access, privacy and confidentiality (Mandell, 1991; Mauthner, 1997; Solberg, 1996). While these issues are not necessarily unique to children, the power differential between researcher and children, and the research setting of the school more sharply focuses these issues. In evaluation studies, where children themselves, as stakeholders have contributed to the purposes and processes of data collection and analyses, some of these standard issues take on slightly different meanings.

In law children are not able to give consent and sign contracts. Parents and guardians carry the legal responsibility until a defined age. General practice in educational research and evaluation in school settings is to seek written consent for access to children from a hierarchy of groups which usually begin with school systems, school principals and parents. Rarely if ever is children's written consent obtained. More often children are given the opportunity at the point of data collection to withdraw within a framework of the given permission of adults. In cases where the children are the key informants, it might be reasonable to seek children's consent to participate before seeking their parents' or guardians' permission.

The issues become more complex where children are members of a class where the unit of study is not the child but the class. Should children, as members of a classroom, have the right to withdraw their consent for observers or participant observers to note and document their behaviours as part of observing a classroom in action; and if so, how should this be done? In some ways this question is less problematic if these children participated as stakeholders in the construction of the purposes and processes of the evaluation in meaningful ways. Through their participation they both been informed, consulted and provided with opportunities to 'consent'. However with all political processes it is important to recognise that even within the group labeled "children" there may the enfranchised and the disenfranchised. With this in mind evaluators still need to clearly address the rights of the individual within the group.

Other ethical issues relating to consent include seeking each child's consent in a way understandable to the child and providing a 'real' choice (as perceived by the child) to participate or not. In both cases the language used and the perceived status and power of the evaluator need to be carefully considered. Solberg (1996) argues that in particular the evaluator has to clearly define their role as 'non-teacher' so that the traditional perspective of 'right answers' for teachers not be applied to questions and conversations between evaluators and children.

Privacy and confidentiality also become issues for children as informants in evaluations in school settings. One issue relates to the need to provide a safe and secure environment for interactions between evaluators and individual children. In a recent study by Downes[1] the preferred practice was one of individual interviews taking place in a large enough space where each pair of researcher and child were in view of another pair but far enough away that conversations were private. On occasions where such a space did not exist the researcher and child negotiated a 'safe' place for the discussion. Again, some of the resolution of the issue was solved by children participating making decision about the issues themselves.

Conclusion

While most of this paper has not directly focused on evaluation of new information technologies in school settings it has provided some background and raised some issues associated with the participation of children in evaluation studies in general. The author also recognises that many of the arguments and ideas in this paper are new to some educators and evaluators and that the proposed model has not been tested in practice. Like the field of information technologies in schools, the field of childhood studies is relatively new to educators and as such both are at embryonic stages of developing useful frameworks and approaches to effective evaluation practice. If this paper has provoked educators to think more deeply about the role of children in evaluation studies it has gone some way to achieving its purposes. What needs to follow is further

[1] The preliminary results of the study have been published in (Downes & Reddacliff, 1997; Downes, Reddacliff & Moont. 1995: Downes. Reddacliff & Moont. 1996)

analysis of the ideas and issues raised; and case studies which attempt to put some or of all of these ideas into practice.

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Serving Multiple Stakeholders: The Practice of evaluation - methodological and substantive issues arising from a major national study

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Abstract

In an ideal world government funded evaluation studies inform decision-making for future policy. The evaluation of the UK Education Departments' Superhighways Initiative (EDSI) was set up to have just this impact. There were several features of the evaluation that made it methodologically unusual: 22 independently planned and funded projects were involved; the evaluators comprised five independent teams; and a 'synopter' was appointed after the evaluation teams had started work to liaise with them and write an overview report. This paper concerns the evaluation of the two Scottish projects within EDSI. The many stake-holders had important, but often competing, interests in the evaluation and the paper addresses the methodological, political and ethical issues that resulted for the evaluation team.

Our initial perceptions of the evaluation task

We were pleased to win the contract to evaluate the two Scottish projects in the Superhighways Initiative. We saw this as an opportunity to influence the development of policy in the area of information and communication technology (ICT). The Scottish Office Education and Industry Department (SOEID) has an established tradition of working consultatively with researchers and evaluators and we knew our report would be given attention as part of the decision-making process. In addition, large areas of north and west Scotland are made up of islands and moorlands, physically cut off from the rest of the UK by mountains and sea inlets, and the resulting isolation of rural communities makes the concept of a Superhighway attractive. For this reason the Scottish Office had already shown considerable interest in developing ICTs, for example by opening up a national debate on the establishment of a University of the Highlands and Islands which would use the Internet as the main means of curriculum delivery across a number of sites in the north and west. The situation seemed ideal for evaluators. We had been appointed by the EDSI Steering Group made up of representatives from all four Education Departments of the UK, but our funding came from SOEID, we would be managed by the Scottish Council for Educational Technology (SCET), and we would be in a position to advise SOEID on the development of policy in an area to which they were already committed. Our evaluation report would feed into the UK-wide evaluation managed by NCET, but our prime responsibility would be to produce a Scottish report to inform the development of education policy in Scotland.

The Projects

The two Scottish projects were very different from one another. We tendered to evaluate both, not with the aim of comparing them, but in order to give us a broader understanding of the issues and allow some economy of scale in using the same research instruments for both where appropriate. It proved particularly useful to evaluate them both as they provided very different models of support for the ICT innovation.

The following descriptions of the projects are taken from the final report.

Modern communications for teaching and learning in Argyll and Bute

The evaluation was of ongoing work in Argyll and Bute to develop an electronic communications network for educational purposes. The network had been in existence for some four years before the evaluation began, and staff in schools and in the Education Support and Development Unit (EDSU) were actively engaged in explorations of the most appropriate ways to make use of the network to enhance the curriculum, to extend opportunities for teaching and learning, and to support the management of schools and co-operatives (cluster groups of primary schools within a defined geographical area). The evaluation is based on the work of two co-operatives and focuses on a variety of school-based initiatives making use of telephone, fax, a closed conference network (Argyll Online) and video communications, which were under way during the evaluation period. The aims of the project were to:

- *develop an effective communications policy and strategy within an educational context;*
- *enhance the curriculum;*
- *support staff development in the use of electronic communications technology;*
- *promote interactive teaching and learning;*
- *enhance the personal and social development of pupils and teachers.*

Superhighways Teams Across Rural Schools (STARS)

This project, based at Northern College of Education, in Aberdeen and Dundee, was designed to create a network of schools in isolated, rural areas across the north and north-west of Scotland, with the aim of enhancing provision for 'able' pupils. Eighteen small primary schools (i.e. with four teachers or fewer), and two secondary schools took part. The project ran for a year, between January and December 1996.

The project made used of electronic communications technology which schools already possessed, and Northern College's existing closed conference system, using FirstClass software. Materials for pupil use were developed by the project co-ordinators at Northern College and delivered to schools over the network. All tasks aimed to promote problem solving and critical and creative thinking skills. Some activities were designed as stand-alone tasks and others required pupils to collaborate across schools before finalising responses and returning these to the project co-ordinators for comment. Pupils communicated via the conference system using e-mail, group conferencing or on-line chat. Towards the end of the project, tasks which required pupils to access information from the Internet were designed for a subset of schools interested in developing skills in this area.

The aims of the project were to enhance pupils' learning and the professional development of teachers using existing electronic communications technologies. The evaluators were asked to focus on:

- *the extent to which appropriate learning benefits an be provided via an electronic communications network to meet the special needs of isolated able pupils;*
- *the extent to which different communications technologies can be integrated to deliver relevant and effective training and professional development opportunities;*
- *the comparative performance of different service and carrier technologies.*

(Hall, McPake and Somekh, 1997).

The Multiple Stakeholders: a brief overview

All educational programmes have multiple stakeholders, but EDSI's origins, structure and purposes made this a particularly interesting and complex feature of the evaluation.

a) Ministers

Viewed as a pyramid structure, the stakeholders at the apex were government ministers who were interested in ICT as a means of improving education in a cost-effective way. EDSI was initiated at the BETT conference in London in January 1995 when the President of the Board of Trade, Michael Heseltine, invited commercial companies to work with the education service to develop ICTs. Ministers wished to use EDSI as a means of promoting a positive image of government leading the way with new technology in order to strengthen the economy and compete more effectively in the world market-place:

> *These new technologies, and the way they are used, will have a profound impact on every one of us. Our new initiative draws together the strengths of our industries and of our education service. It builds upon the sound regulatory structures and frameworks for competition which the Government has put in place. It will lead to real progress in helping learners throughout their lives - and hence help the vital task of keeping Britain competitive in the 21st Century.*
>
> Michael Heseltine, Deputy Prime Minister and First Secretary of State (DfEE, 1995)

The evaluation was carried out during the period leading up to the general election of May 1, 1997. During this period politicians from both the Conservative government and Labour opposition made frequent reference to their policies for ICT as a means of promoting a positive public image for their party.

b) Civil servants in London

EDSI appears originally to have been conceived by civil servants in London (in collaboration with government ministers) as a strategy for encouraging commercial companies to put funding into the development of ICT in education. In a very real sense EDSI was not a programme since it had no programme director, no common structure and no central funding. It was a collection of 22 projects selected by the Education Departments to represent a range of the best ICT initiatives. Its significance was huge, however. It represented the kind of partnership between industry and education that the government at the time valued highly. It also had the potential to bring the very latest state-of-the-art technology into classrooms. Civil servants clearly wished to present it as an example of how the UK led the field by comparison with our European and global competitors:

> *'In our view this is probably the biggest and most coherent evaluation of an initiative of this kind in the world. We all think we are heading for a step change in the way technology is used in schools.'*
>
> Robin Ritzima, EDSI Conference, London 18, Nov. 1996

Once the projects were selected and the evaluations were commissioned, civil servants needed firm evidence of added value in either the quality or quantity of educational experiences as the basis for recommending further policies to ministers. They were working to tight time-frames with ministers anxious to have access to reliable information during the period running up to a general election. At the evaluators conference in London in November 1996, civil servants made it clear that they wished to maintain some control over the evaluators, particularly with regard to the style and structure of research reports.

c) HMI in Scotland

In Scotland, HMI work in close partnership with the SOEID, and have a role in education policy development as well as some control over resources to support initiatives. Although they appear to have had little say in the original design of EDSI, Scottish HMI were very supportive of it and, not surprisingly, were concerned to ensure that the evaluation gave good value to Scottish education. An early meeting was set up, with representatives of SCET in attendance, to give an informal 'steer' to the evaluators. A decision was also taken to appoint three National Development Officers to provide support for those Scottish projects which had not been selected to be part of EDSI: they would be given advice, guidance and contacts to other projects, but no additional funding. In October 1996 a Superhighways Task Force was set up, under the leadership of HMI Stuart Robertson, with a brief 'to enable the Department to respond most effectively to Superhighways and related developments in the context of schools.'

d) Project teams

Both project teams were initially unclear what benefit, if any, they would derive from an external evaluation. It was necessary for the evaluators to negotiate to work on their behalf as well as on behalf of SOEID and the EDSI Steering Group that met in London. Both teams were concerned that the evaluation should not damage their relationships with project participants (teachers, schools and education authority officers) by creating an additional work load for them. In one case, the project director accompanied us personally on the small number of visits we made to schools, thereby making a considerable demand upon his time. In the other case, some anxiety was expressed that by visiting schools we would reflect badly on the project team which did not have funding to make similar visits themselves. (It must be remembered that travel costs to visit schools in this project were very high because of the distances involved and the need in many cases to travel by air because of the poor infrastructure of roads and ferries.) Both project teams needed reassurance that the evaluation would not spoil their chances of future funding through attracting adverse publicity. In one case, there was anxiety about the impact of the evaluation upon existing links with a commercial sponsor.

e) Commercial sponsors

Only one of the projects had a commercial sponsor (the other merely had representation from commercial companies on its Steering Group) and as this sponsorship had not been set up to promote participation in EDSI there was no direct contact between the evaluators and the sponsor. Since most of the other EDSI projects had substantial commercial sponsorship, there were some expectations from the EDSI Steering Group of greater involvement of this sponsor in the evaluation, but commercial sensitivities meant that it did not prove possible to achieve this.

f) Teachers

The teachers in the schools, as one would hope and expect, were primarily concerned with giving children a good education. In schools with an existing tradition for using computers, teachers were keen to support children's use of ICT and took pleasure in their involvement with the projects. A small number of schools in the College-led project were selected by LEA advisers because they did <u>not</u> have an existing tradition of using computers; these teachers also supported children's use of ICT, but had a natural preoccupation with learning to use the equipment (for which they had very little support). With regard to the evaluation, teachers' main concern was that they should not have to take on additional work that would interfere with normal teaching (a concern that we fully shared). Two teachers served on our evaluation Advisory Group and appeared to enjoy this role once it was agreed that SOEID would pay their substantial travel costs to Edinburgh for three meetings and provide teacher supply cover in their absence.

g) Students

The children in the project schools were universally enthusiastic about all aspects of the projects, including the evaluation. They worked on our behalf by answering questions about their work and in some cases logging the use of ICT in their school over the period of a week. We were aware that they were our most important stakeholders. However, they had no power in their own right to influence the evaluation and our contact with them, given the huge distances involved to travel from Edinburgh to their schools, was insufficient for us to create a bigger role for them in the evaluation.

h) Education Authority (EA) advisers

EDSI took place at a time which caused LEA advisors in Scotland great difficulty because it coincided with local government re-organisation. There was a major hiatus leading up to April 1 1996, when the new authorities took control. Thereafter there was a period when services were severely cut back, and it was many months before any of the authorities were in a position to establish new initiatives. In our EA-based project re-organisation meant that new schools joined the authority and had to be inducted into the co-operative approach from scratch; at the same time, the resources for computer support were considerably reduced (perhaps because in a larger EA it had been possible to provide enhanced support for a flagship ICT project). In both projects, EA advisers made it clear that the evaluation must not interfere in any way with on-going work. In the case of the College-based project, EA advisers were anxious that the project itself should not make extra demands on teachers and there was some confusion about whether involvement in development work would be welcomed by teachers or perceived as unwanted additional work.

i) SCET

The evaluation of the two Scottish projects was managed by SCET. This meant that SCET issued us with our contract and was charged with ensuring that we carried out the work within the agreed time-frame. SCET acted as our link with SOEID, although we also had direct contacts with SOEID through our other work at SCRE. Initially we had no expectation of any link with NCET in relation to delivering our contract. However, we were gradually drawn into the overall evaluation strategy of EDSI, co-ordinated by NCET. Thereafter, we turned to SCET for support when we needed it and attempted to keep SCET staff informed of what we were doing with NCET. SCET once again had an important role at the end of the evaluation, in negotiating with us how to make best use of our report within Scotland. Since the needs of Scotland were quite distinct from those of EDSI as a whole, this involved us in substantial re-writing of the report to the specification of SCET and SOEID.

j) NCET

Our link to NCET was never clear, but it became increasingly strong over time. NCET was responsible for managing all the EDSI evaluation teams except ours. A full time EDSI manager was appointed at NCET in May 1996 [CHECK], after all the evaluation teams had begun work. Her role included negotiating with evaluation teams to ensure good links between them, running conferences and acting as a go-between for the synoptic evaluator (see below). NCET played a key role in ensuring that the evaluation as a whole conformed with the needs and expectations of civil servants and ministers in London. As the evaluation progressed we worked more and more directly with NCET to ensure that our report could be incorporated in the synoptic report with those of the other teams. However, as there was no direct link between NCET and SOEID it was necessary for us to negotiate with SOEID before concurring with changes in strategy.

NCET's needs constantly changed, presumably as the needs of civil servants in London changed in response to the development of policy. The evaluation was probably sufficiently large to make it difficult to establish clear roles and relationships, but this was undoubtedly made much harder because the projects had all begun work in their own way before co-ordination from NCET was put in place.

k) The synoptic evaluator

The decision to appoint Peter Scrimshaw as a synoptic evaluator came as a surprise to us, and we believe to all the evaluation teams. It had always been clear that there would be an overview report but we expected it to be produced by NCET rather than by a commissioned evaluator. The synoptic evaluator constituted another stakeholder in his own right. His report would clearly have a high profile and must represent the work of the evaluation teams, as a whole, to ministers and civil servants. Like all evaluators he had the responsibility to provide wise advice which might influence policy and the spending of public money. Since ministers wanted to present EDSI as a flagship programme within Europe he would have to bear this in mind when writing his report.

Peter's first step on being appointed was to set up visits to all the evaluation teams and, as far as possible, to the project teams and schools. One of the projects within Scotland regarded this as external interference which would impose additional calls upon the time of teachers and project personnel. This put us into the role of intermediary between the projects and the synoptic evaluator.

Issues arising from serving multiple stakeholders

> The 'stakeholder assumption' is the idea that key people who have a stake in an evaluation should be actively and meaningfully involved in shaping that evaluation so as to focus the evaluation on meaningful and appropriate issues, thereby increasing the likelihood of utilization. (Patton, 1982, p. 59)

It was our aim to carry out an evaluation that would be useful in informing policy and practice. Our preferred method was to work on behalf of all the various stakeholders. However, this was not without difficulty since it will have become clear from the previous section that the stakeholders' assumptions and needs varied considerably. A contributory factor was the loosely-coupled nature of EDSI, comprised as it was of 23 separate projects, all with different aims and involving very disparate user-groups.

In this section we want to discuss some of the issues that arose from these differences between stakeholders and had an influence upon the conduct of the evaluation.

Our loyalty to several stakeholders was contractual (civil servants in London, HMI in Scotland, SCET and NCET) and to others carried a practical imperative because they controlled our access to information (project teams, teachers, education authority advisers). But, in any case, our criteria for a good evaluation were that it should be 'democratic and fair' (Karlsson, 1996, p. 407) and this presupposed that we would serve the interests of all.

In practice, all the issues discussed here forced us to take a position and negotiate with individual stakeholders to reach a resolution or compromise. There was certainly no possibility of adopting a detached stance and construing our role to be no more than collecting, ordering and disseminating factual information. Our role clearly involved taking decisions on practical, moral and ethical grounds. As far as possible I believe we attempted to analyse the part played in this by our own subjectivities (Peshkin, 1988) although this was often difficult in the highly pressured situation of working to tight deadlines. It was further complicated by the fact that we were a newly formed team[1] and brought some different assumptions to our role as evaluators. The obvious lack of objectivity that characterised many of the data we needed to collect, analyse and report made it more than usually clear that our role involved positioning ourselves strategically and politically. We had to exert control or accept loss of control within a highly charged political game in which some stakeholders had much to lose.

> "It is obvious that the evaluation is a conflict-laden and politically powerful activity." (Karlsson, 1996, p. 406)

a) The unusual design of the initiative

As we have already said, EDSI was not a development programme in the ordinary sense. It had no central direction, no common source of funding and no overarching objectives. In the context of IT-related development programmes with their history of over-inflated aims, large-scale funding and disappointing take-up (House, 1974, pp. 213-4; Kemmis, 1987), EDSI's design can be seen as visionary - it was also an inspired solution to the need to create a high profile initiative at very low cost.

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[1] John Hall and Joanna McPake had worked at SCRE over a number of years. Bridget Somekh joined SCRE in February 1995 after working for eight years at the Centre for Applied Research in Education at the University of East Anglia.

The consultation paper, Superhighways for Education, issued in May 1995, asked for feed-back on key questions relating to the educational uses of broadband ('Superhighway') and narrowband network technology; it offered 'to fund the evaluation of innovative new proposals'; and it 'invited specific collaborative projects which would benefit from evaluation to come forward.' (A close reading of the text revealed that 'collaborative' meant collaborations between industry and education).

b. Confusions over government funding

Before reading the document most of those likely to become involved believed that government would be funding a major new initiative. This confusion unfortunately continued in some cases. As a result, both the Scottish projects put themselves forward under the misapprehension that if they were accepted for evaluation they would be given financial support. Both sets of project directors were considerably disappointed when they received no funds and felt it was inappropriate for the evaluators to be funded when there were no new resources for the projects. They were further disappointed when they heard that Scottish projects not selected for EDSI would be supported (rather than evaluated) by SOEID project officers (although this did not mean that special funding was made available to these other projects).

Implications for the evaluators

In the early stages of the evaluation, it was necessary for us to assure both project teams that the evaluation would work on their behalf as well as on behalf of government. As far as possible we promised to provide them with some support as a by-product of the evaluation. Although both teams co-operated with us fully, there was inevitably a tension in the relationship arising from their initial sense of disappointment and our need to keep to a minimum the additional work required of them by the evaluation.

As work progressed, the lack of funding posed a problem in reporting the outcomes of the two projects. In neither case were they really Superhighways projects. Early in the course of the evaluation one of the project directors said, 'We have to face the fact that there is no Superhighway in northern Scotland.' Lack of funding meant that no in-road was made to rectifying this initial disadvantage. How were we to report this? Both projects achieved a great deal given the limits of the technology available to them. In addition, the project that was EA-led provided an excellent example of the use of video-conferencing using ISDN lines, work that had been set up with small-scale commercial sponsorship prior to EDSI.

The other project was useful in demonstrating what could - and what could not - be achieved using narrow band technology (and ISDN in the case of a few schools). We were impressed by the achievements of this project and the important evaluation criterion of 'fairness' suggested that we should emphasise these. However, we clearly had a responsibility to report what had been lost by general lack of funding and lack of access to the Superhighways infrastructure in particular.

c) Confusions over commercial sponsorship

In *Superhighways for Evaluation*, there is no clear reference to the need for commercial sponsorship in the 'guidance and criteria' for selection of projects for 'government sponsored evaluation'. In fact, the whole document is based on the assumption that commercial sponsors would provide backing for projects, thereby increasing the educational use of broadband technology. However, for the uninitiated reader, the only clue to this lies in the statement that 'the costs of participating in a project should be minimal to educational institutions.' The attraction for commercial sponsors must be assumed to have been that their products would be given a high profile by participation in EDSI and that this would provide them with future market opportunities with government and other public sector users (LEAs, schools).

Both of the Scottish projects had links with commercial sponsors, but in neither case was any commitment made by the sponsors to provide additional funding if the project was accepted for evaluation. In one case the link was extremely tenuous, involving mainly the college's former audio-visual unit that had been re-launched as a company in order to engage in commercial activity. Although commercial interests were represented on the advisory group of this project, no sponsorship was forthcoming, save from the college's own resources. Although it was possible to proceed on the basis of almost all contacts being made electronically, it was clear that lack of funding substantially limited what the project was able to achieve: for example, they were unable to appoint a project officer, with the result that all project activity was undertaken by the three lecturers concerned in their 'free' time; and they could not visit schools or set up meetings with teachers. In the case of the EA-based project, the link with the commercial sponsor was an important factor in the evaluation because the project team was naturally wary of the possibility of negative publicity which might not give the sponsor the expected return in terms of positive publicity and marketing opportunities. Moreover, other aspects of the partnership with the sponsor involved software development work and, where this related to EDSI, the evaluators had to respect the need for commercial secrecy.

Surprising as it seems with hindsight, we have to say that it was only at the evaluation meeting in London in November 1996, that it became clear to us that commercial sponsorship was intended to have played a large part in the establishment of EDSI projects. The Scottish project teams, and ourselves, were surprised that commercial sponsors were invited to attend the conference. In the case of the project that had on-going commercial sponsorship dating from before EDSI, it was not clear who was responsible for inviting them. In the event no representative of the sponsor attended the conference.

Implications for the evaluation

The lack of collaborative partnership with industry in the two Scottish projects drew our attention to the inherent problem of depending upon commercial sponsors to support development of the Superhighway in remote and inaccessible rural areas such as the north and west of Scotland. It was clear that many of the EDSI projects had been set up as a result of commercial sponsors wishing to participate in a government initiative. They were either built upon existing commercial initiatives and partnerships, or were set up as demonstration projects in response to the EDSI call. Commercial interest was the sole reason for the investment, albeit with the aim of proving the sponsor sensitive to, and capable of understanding, educational needs. Commercial interest could never have been served by setting up projects of this kind in remote rural areas, or at least not on any large-scale.

It was imperative for the evaluation to draw attention to this problem, particularly as the work of the projects made it clear that the educational advantages of participation in Superhighways projects are great - indeed we can make a good case for saying that the educational advantages increase in inverse proportion to the likelihood of attracting commercial sponsorship.

In the case of the project that had an existing link with a commercial sponsor, considerations of commercial secrecy served to limit what we were able to report. Specifically, we had to omit some technical and financial information.

d) *Problems arising from the timing of project work and the evaluation*

There were two quite different factors relating to timing that caused problems for the evaluation, although both, in different ways, related to delays in the start.

The first concerned incorrect information that was given to the Directors of both projects, before we were awarded the evaluation contract, to the effect that the evaluation would run between January and March 1996. This seems to have been an error resulting from SCET receiving incorrect or misleading information from London. However, it caused the evaluation team problems in our initial contacts with projects, particularly since we did not receive our contract until mid-February and made our initial visits to projects early in March. The main problem related not to a late start, but to the misunderstanding this had caused as to the scale of both the project and the evaluation. Both the project teams were ready to welcome us to evaluate small-scale areas of work that could reasonably be explored in a three month period. It was necessary for us to radically re-negotiate the access to their work. In the case of the project that was on-going the main problem was in the increased demands the evaluation would make upon their time. They were also more concerned about the possible negative effects of the evaluation when it became clear that it would be a much more substantial investigation than they had at first envisaged. In the case of the second project, some of their initial project planning had to be substantially revised, in particular, gaining support from EA advisers to work with schools over a much longer period of time than they had at first requested. In both cases, there is no doubt that local government re-organisation in April 1996 was a major factor in the anxieties of EA personnel.

The second related to the inevitable delay in getting ICT projects started. It was clear from the time-frame of reporting, communicated to us by NCET in July 1996 - and included in the contracts of all the evaluation teams they managed (i.e. not in ours) - that the EDSI Steering Group assumed that projects would be ready to be evaluated immediately. Thus the first interim report was required in March 1996 and the second in September 1996. It may be that ministers and civil servants assumed that the projects that had come forward to be evaluated were already 'up and running' concerns. In the case of the Scottish projects, one was and one was not. It may be, however, that there was yet again a misunderstanding of the time needed to establish a project of this kind from the date when funding is announced (in this case, funding of the evaluation) to the date when ICT equipment is in daily use in classrooms. In our experience, as evaluators, delay of this kind is always a factor in projects involving the use of ICTs.

Implications for the evaluation

I believe that the over-hasty time-frame for reporting the evaluations caused misunderstandings between the evaluators and the EDSI Steering Group. Most teams were only able to report on the early activities of projects by September 1996; and this appears to have created anxiety about the evaluators' ability to report on the issues specified. The form of reporting was, subsequently, severely circumscribed, in a way which we will return to in a later section.

In relation to the Scottish projects, on a subtle level, it created an impression of being overlooked which caused some tension between various stakeholders, and between them and the evaluation team. Much more seriously, it meant that we had to rush to produce a report which we had not expected to have to write, in a time frame that had not been agreed. There was a repetition of the same problem in December 1996 because it emerged rather late that all the other evaluation teams were under contract to produce a draft final report in January 1997. These unexpectedly early deadlines were exceptionally difficult to achieve, given the code of practice that we had established with project teams which ensured that they had access to draft documents and could comment upon them before they were submitted to SCET/SOEID/NCET.

e) Representing Scottish interests

There were problems for the evaluation team in ensuring that the concerns of Scottish education were properly represented in the EDSI evaluation as a whole. This stemmed from very real ignorance of the Scottish education system, Scottish education policy and Scottish geography among EDSI personnel in England.

Scotland has a completely separate education system: instead of a mandatory national curriculum, it has 5-14 curriculum guidelines which are being implemented gradually; instead of GCSE and 'A' level it has 'standard grade' and 'highers'; it has a General Teaching Council which regulates and oversees the qualifications and conditions of service of teachers; and HMI inspection of schools in place of OFSTED. In terms of education policy, HMI has a budget which enables small-scale educational development work, but there is no mechanism for central funding of IT equipment for schools of the kind that has been common in England and Wales since the DTI Micros in Schools initiative of the early 1980s. For this reason, SCET is a very different organisation from NCET, existing largely as a commercial enterprise, providing software and services to schools and EAs, rather than being like NCET a government QANGO that manages government-sponsored initiatives and receives a budget from the DfEE to support the implementation of policy. These are significant differences which have an impact on the purposes of the EDSI evaluation and the kind of policies that it would be possible to introduce on the basis of its outcomes.

Scottish geography gives a completely different meaning to the word 'rural' from that ordinarily understood in England and Wales. The problems are much more akin to those experienced in northern Norway (Solstad, 1992). There are still many areas of the north and west in Scotland where road, rail and ferry links are so poor that children have to leave home and live in hostels during the week in order to attend secondary school. These are the areas where peripatetic specialist teachers can only reach schools in a 30 mile radius of their base; and where many teachers can only attend in-service training events and meetings if it is possible to return in time to catch the last ferry back to the island where their school is located. Contact between some islands and not-so-distant parts of the main land may necessitate a two-stage air flight via Edinburgh or Glasgow.

It had been made clear to us from the start that SOEID and SCET wanted a separate Scottish evaluation report. For example, we were asked to ensure that we did not limit ourselves to reporting on issues relevant only to rural schools, or to primary schools. Despite the particular foci of the projects we were evaluating we were to produce a report that would inform the development of ICT use in all Scottish schools.

Implications for the evaluation

Lack of understanding of these differences made it difficult for the Scottish evaluation team to argue for the need to give Scotland special consideration in the synoptic evaluation report without appearing to be advancing unnecessary special pleading. Yet the need to feed the evaluation of the two Scottish projects into a synoptic report representing all 23 projects suggested that matters of particular relevance to Scotland would be bound to be lost if they were not given separate consideration. The most obvious problem was in the lack of a Superhighways infrastructure in Scotland and the enormous difficulties involved in providing one in the future. Already many areas of rural Wales have access to broadband - for example in Powys there is a lease line linking the Council offices in three districts and this was extended to all secondary schools at the time when the careers service was privatised. To establish a similar cabling link in Scotland would require very much more substantial funding and is very unlikely to happen in the foreseeable future without government support.

The complex management structure of EDSI, with our formal responsibility to SCET and our informal but much more demanding responsibility to conform with decisions taken by NCET, meant that we often needed to negotiate between different stakeholders and consult Scottish HMI to gain consent for what had been agreed. Occasionally we had to be prepared to insist upon not conforming to requests from NCET that would have damaged relationships with one or other of our Scottish stakeholders. The most difficult issues arose when we were writing the final report and will be dealt with in the next section.

f) A synopter and a common framework for reporting: implications for the evaluators

The inclusion of a synoptic evaluator in the design of the evaluation, after contracts with individual evaluators had been signed, posed a number of potential problems for evaluators. The ability for individual evaluators to influence policy - i.e. the political role of the evaluator - was seriously eroded, except in the case of the Scottish evaluation where SOEID could be relied upon to pay at least as much attention to the Scottish report as to the synoptic one. Moreover, since evaluation is not a neutral activity but involves the exercise of judgement at every stage of data collection, analysis, interpretation and reporting, it is a not a trivial matter to relinquish control over both the style and content of the report. This was a problem that was only partly resolved by the commitment the EDSI Steering Group made to publishing each individual report as well as the synoptic report. Important subtleties of meaning would be bound to be lost in the production of the synoptic report and many people would only read this overview document.

A second, and more serious, problem was the imposition of a framework for reporting. The EDSI evaluation involved five teams of evaluators working with 23 projects and a synoptic evaluator producing a synthesis of all the reports. The DfEE was anxious to ensure that reports were written in a way which would enable the synoptic evaluator to report fully on all those areas that were of interest. Therefore, at their request, Peter Scrimshaw produced a framework of chapters and section headings for all the final reports to follow. Without this kind of structure it is certain that each of the five teams would have placed emphasis on those aspects which were of particular interest in the projects they had evaluated and would have addressed other questions much more cursorily, if at all. If the main interest is to compare different kinds of technology as they are used in different kinds of projects, and the assumption is that the knowledge produced will be mainly factual and can be generalised across contexts, then this is a sensible approach. However, this begs a lot of questions.

SCRE evaluations are always written in a readable style, as far as possible answering the questions that the sponsor has specified, and doing so in such a way as to present a fair account that respects the rights of all those involved. However, we work to professional standards, avoiding drawing conclusions from comparing things that are disparate or making claims to accuracy or generalisable truth from single instances. We take care to use language that indicates the level of certainty of each statement as precisely as possible; and we ensure that any possible biases in our own judgements are signalled by giving an account of the assumptions upon which we have based out work. None of this was possible once we had been forced to accept a pre-determined framework for our report.

Moreover, we had lost the ability to shape the reports to the needs of other stakeholders. The very tight word limits imposed on us meant that we were not able to deal with any aspect of either project's work in sufficient detail to satisfy the expectations of participants. It was also impossible to include rich descriptions, with commentary, that would enable interpretation of more subtle aspects of work we had observed, or to provide vignettes to catch readers' attention and anchor an important point in their memories.

All evaluators who use qualitative methods have to grapple with difficult questions relating to the nature of knowledge, the kind of evidence that can be used to support the development of theory from a detailed study of one or two cases, and the positioning of the evaluator her or himself within the evaluation report (see e.g. Greene, 1996). Although there is no place for discussion of these issues in reports to sponsors, there are serious implications for the professionalism of the evaluator if they have to be ignored in reporting the evaluation. In effect, this is what happened in this case because there was no freedom to shape the report according to methodological principles.

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GENOVA

A COLLECTION OF
EVALUATION STRATEGIES AND TOOLS

Prepared for the IFIP Working Group Conference 3.5
Santa Margherita Ligure, Italy
April 1 -4, 1998

Gail Marshall Ph.D.

WHAT HAS BEEN ACHIEVED THUS FAR

FOCUS GROUP REPORT

WORKING CONFERENCE

ISRAEL, 1996

The Work of the Professional Group Israel 1996

In beginning its discussion of evaluation in technology-equipped settings, the Professional Group identified many key issues that must be considered in designing and conducting evaluations:

- What is the role of the evaluator?
  - There may be many different roles such as: truth teller; data provider; data interpreter; partner; insider/outsider; story-teller; judge; consultant;
  - The evaluator may be more like a scientist enquiring at the cutting edge where there are no definite answers, or more like an engineer intent on improving the production line for a rocket.

- How does the evaluator deal with ethical and moral dilemmas?
  - These dilemmas lead to conflicts about role;
  - Evaluators have responsibility to different stakeholders and interest groups;
  - There must be respect and care for individuals - the evaluator often holds considerable power in a situation where people might lose their jobs as a result of the evaluation.

- Who is the client?
  - The sponsor?
  - The participants?
  - The policy makers?

- What is the purpose of the evaluation?
  - Who do you write the reports for?
  - Evaluations may be mainly concerned with contributing to public knowledge, to the learning of policy makers, to the process of accountability for the spending of public money;
  - In which cases is there a need for answers?
  - There may be (should there be?) a marketing dimension to evaluation;
  - Where do you draw the boundaries around what is being evaluated?
  - Is evaluation in schools sometimes/always a vehicle for teacher development?
  - Evaluations can be a mechanism for support or a vehicle to promote change;
  - Evaluations may measure the attainment of goals (knowledge acquisition, social and moral competence, data literacy, media literacy).

- What is the climate under which evaluation is conducted?
  - Evaluations need to take account of the culture - is it punitive? is there a climate of deficit or of openness?
  - There may not be a culture of asking hard questions.

- How political is the evaluation process?
  - There are implications for the funding of initiatives;
  - Evaluators cannot avoid promoting and institutionalising particular sets of values;
  - There is the naiveté of some clients;
  - There is an issue of co-optation;
  - What effect does the evaluation have on what is taking place?

Focus Group on Evaluation, in D. Passey and B. Samways (eds.). *Information Technology: Supporting change through teacher education.* Chapman & Hall, London, 1997.

professional activity. The analogy of the spider spinning a web and being caught in the web was offered as a metaphor for the situations in which evaluators often find themselves.

The Professional Group stated that evaluation changes what it evaluates. This poses a moral dilemma which discomforted some members of the group. However it was recognised that this can have a positive outcome. For example, questioning teachers and other stakeholders about what has been observed can change teachers' perceptions and future actions. In this way evaluation serves as an important component in the teacher education process. A further development of this approach would be Action Research, in which teachers collaborate with external researchers in a process of data collection, reflection, action planning, and evaluation - a process that repeats the cycle often as each member of the team defines and refines questions, observations, and analyses. In these collaborative evaluations, participating teachers often receive certification as an acknowledgement of their contributions.

It was agreed that framing questions and deciding how to answer those questions was a major concern of evaluators. Techniques such as informal observation, the use of rating scales to assess the level of teachers' interest in using IT, and analysis of video-taped lessons were suggested as useful ways for evaluators to break out of the pattern of administering end-point tests and comparing groups on such outcome measures. In fact, the group rejected the simplicity of the pre-/post-test model as trivial, inadequate, and misleading. In their view such evaluation strategies fail to capture the richness of the problems associated with the introduction, integration, and institutionalisation of IT.

There was general agreement that there is often an important role for teachers, students, parents, and the community to be participants in the evaluation process, and that this often enables them to act directly on the outcomes. It was suggested that children could often take part in evaluation activities and if they were taught some of the evaluation process, that this could have a beneficial effect on their development as learners.

It was also agreed that when we are talking about evaluations in technology-equipped settings we are not just talking about the use of tools; instead we are talking about the process of change, the conditions required for change, and the effects of change. The evaluators, it was agreed, were agents of change and should address the question of the purpose of education as they examine the acts within the educational context.

At that point in the discussion it became clear that it was important to specify the level of analysis - school level, classroom level or student level and whether the problem under investigation was the question of using IT with the current curriculum and evaluating all the aspects of that process or whether the problem was to examine the process of changing the curriculum and thus changing the ways students perform school-based tasks and acquire knowledge. While it was acknowledged that evaluators may now have to address the first set of questions, that increasingly the questions are likely to be directed at why and how the curriculum will be changed as IT's educational potential is more completely explored. Similarly it was agreed that evaluators must inquire about the effects of those changes on the school, the teacher, the student, and all the other stakeholders. It was acknowledged that different questions will follow from different contexts, from the mandate to the evaluators, and from the evaluators' sense of the logic of inquiry.

Focus Group on Evaluation, in D. Passey and B. Samways (eds.). *Information Technology: Supporting change through teacher education.* Chapman & Hall, London, 1997.

not aware of the criteria applied in evaluative situations and may not understand the full import of those criteria as they apply to the models and to the situations. This may mean that continuing professional development for evaluators and consumers of evaluation must include a knowledge of the models which can be applied and a knowledge of the range of criteria applicable to those models. There was a tension within the group on the advisability of setting guidelines for evaluators' professional development, with some members saying that evaluators must answer to themselves and that acting with reflection upon the issues surrounding the evaluation is sufficient. But it was agreed Jim Ridgway's discussion of Vygotsky's work, presented in the conference keynote, on the development of tool use was a fruitful conceptualisation for reflecting on the problem of change in behaviour.

The fundamental division between epistemological views - ministries and other funders typically seeing education in behaviourist terms and practitioners often seeing education in constructivist terms - was seen as a problem and it was suggested that educators must adopt an "instrumentalist" stance when they present their findings. Similarly, the caution was raised that the evaluator must plan how the evaluation reports and summaries will be used, and plan for different levels of description for different audiences, and it was agreed that evaluations cannot be considered as abstractions, but must be thought of in terms of the environments in which they are conducted.

Discussion also addressed the question of whether there would be a revolution or evolution of educational practice as a result of the use of technology in school settings. Some members of the Group said that governments were working to make radical change which was needed, while others said government was seeking revolutionary change in areas where past practices had been *perceived* to fail and there was a danger of losing good practices which do not require technology under the governments' demands for increased student performance.

There were clear cut national differences within the Group, related to differences in cultural patterns, differences in goals for schooling, and differences in the stages of implementation of technology. For example, differences in epistemological perspectives yielded differing views on what questions should be asked and how those questions should be answered. It was acknowledged that these differences were an important part of the educational practice of individual countries, but that those differences should be analysed by evaluators as they set about their work.

It was clear that current evaluation practice must begin to look to the future and devise and use taxonomies of educational objectives that accord with the behaviours that futurists tell us will be developed and applied as a result of our interactions with technology in school settings. Reanalyses of taxonomies such as Bloom's taxonomy of educational objectives have been conducted and they specify how the objectives are enhanced or changed as a result of the technology revolution. Currently many evaluators are working with models and objectives suitable to a factory or small land holding farmer, but the Group agreed that the 21st century tools and challenges call for a re-examination and a re-formulation of the evaluators' tools and methods. Such a re-examination would be a fruitful task for subsequent Professional Group activities.

It was also suggested that subsequent Professional Group activities assume the task of formulating sets of criteria that are applicable to the different stakeholders - ministries of education, teachers, school administrators, and the community at large. Guidelines are also needed on how to educate the stakeholders in acting on the evaluations' findings and recommendations. So the work of the Israel-based Professional Group on evaluation, while informative and wide-ranging, is far from complete as it applies to the manifold questions and issues facing evaluators in technology-equipped settings.

The Chair and Rapporteur wish to acknowledge the significant contribution made to this report by Rachel Cohen.

Focus Group on Evaluation, in D. Passey and B. Samways (eds.). *Information Technology: Supporting change through teacher education.* Chapman & Hall, London, 1997.

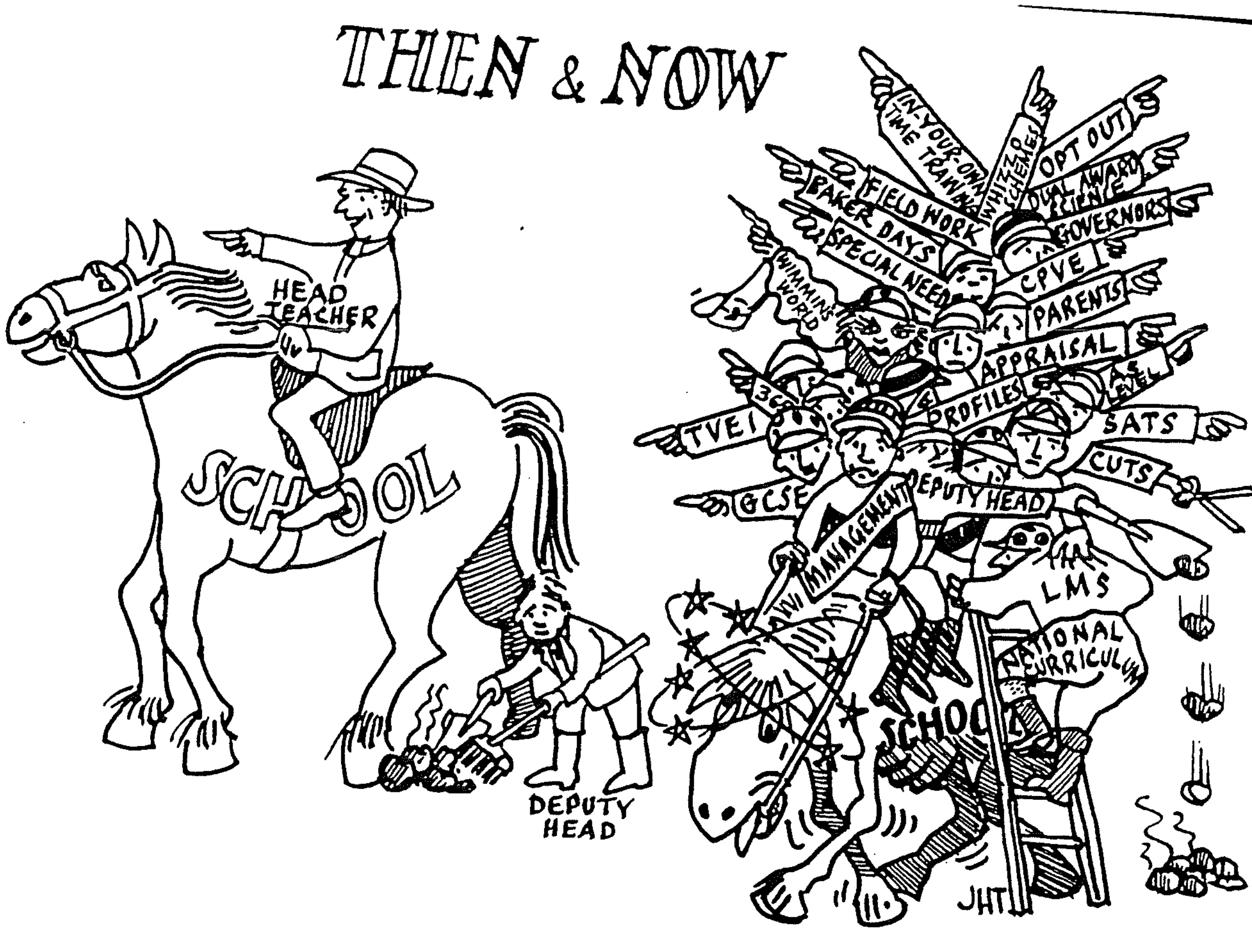
THEN & NOW
HEAD TEACHER
SCHOOL
DEPUTY HEAD
IN-YOUR-OWN TIME TRAINING
WHIZZO SCHEMES
OPT OUT
DUAL AWARD SCIENCE
GOVERNORS
FIELD WORK
BAKER DAYS
SPECIAL NEEDS
WIMMIN'S WORLD
CPVE
PARENTS
APPRAISAL
AS LEVEL
PROFILES
TVEI
SATS
CUTS
GCSE
MANAGEMENT
DEPUTY HEAD
LMS
NATIONAL CURRICULUM
SCHOOL
JHT

Figure 6.1

FRAMEWORK FOR RECORDING ACHIEVEMENT

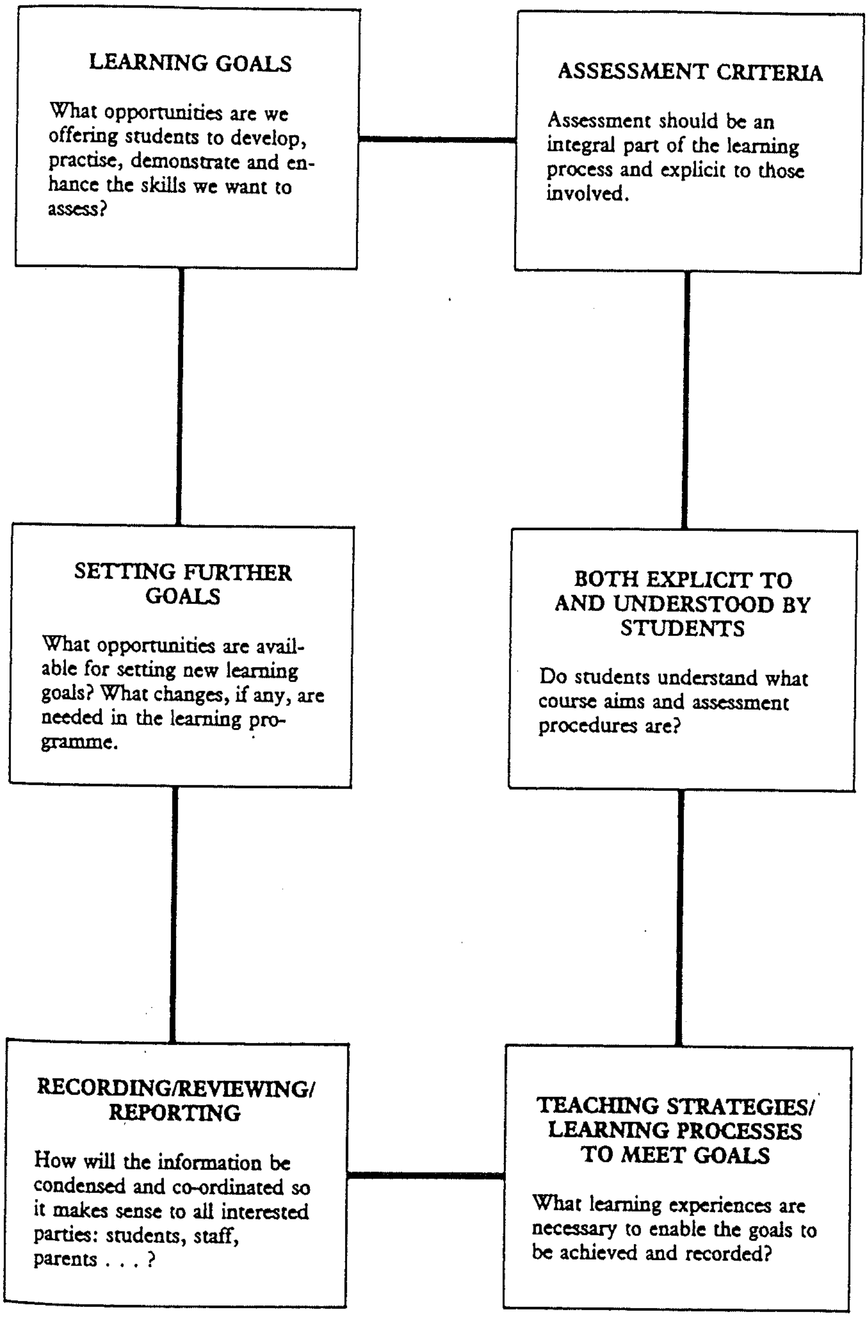

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Figure 1.3
Assessment Alternatives

Assessing Processes	Assessing Products
• Clinical interviews	• Essays with prompts and scoring criteria
• Documented observations	• Projects with rating criteria
• Student learning logs and journals	• Student portfolios with rating criteria
• Student self-evaluation (oral or written)	• Student demonstrations/ investigations (expository or using the arts)
• Debriefing interviews about student projects, products, and demonstrations (student explains what, why, and how, and reflects on possible changes	• Paintings, drama, dances, and stories with rating criteria
• Behavioral checklists	• Attitude inventories, surveys
• Student think-alouds in conjunction with standardized or multiple-choice tests	• Standardized or multiple-choice tests, perhaps with section for "explanations"

Herman, J., Aschbacher, P.R., and Winters, L. *A Practical Guide to Alternative Assessment*, Association for Supervision and Curriculum Development, Alexandria, VA, 1992.

CAP's New Assessment Types

CAP is developing four types of assessments:

- Open-ended problems
- Enhanced multiple-choice questions
- Investigations
- Portfolios

These four types of assessment differ from each other in many ways, as summarized in Table 2. CAP will use all four types in order to assess as many dimensions of mathematical power as possible. The specific combination of the four assessment types will be determined by extensive piloting and field testing. This combination will evolve and change as new research data become available.

TABLE 2

FEATURES OF FOUR TYPES OF ASSESSMENT[1]

	Nature of feature, by type of assessment			
Feature	*Enhanced multiple-choice questions*	*Open-ended problems*	*Investigations*	*Portfolios*
Time per task	2-3 minutes	15-45 minutes	2-3 hours	2-3 weeks
Calculator	Yes	Yes	Yes	Yes
Manipulatives	No	When appropriate	Yes	Yes
Correct answer	One	Many	Many	Many
Who creates responses?	Item writer	Student	Student	Student
Scoring	Answer key	Judging	Judging	Judging
Model of good instruction	No	Yes	Yes	Yes
Collaboration	No	No	Yes	Yes
Student self-assessment	Little	Some	Much	Most
Usefulness to teacher	Some	Very much	Very much	Most

California Assssment Program, *A Sampler of Mathematics Assessment*, California Department of Education, Sacramento, CA, 1991.

SAMPLES OF ASSESSMENTS

C. Continuity Through Change: Students will understand that matter, energy, and life respond to change and yet continue.
D. Interaction in a System: Students will understand that matter, energy, and/or life forms/units interact in systems.

Matter and Energy

E. Structure and Form: Students will understand that forms/units of matter, energy and life can be identified by the structural characteristics of each. These can be classified according to similarities and differences.
F. Structure and Function: Students will understand that characteristics of life systems explain their functions; properties of matter and energy explain their effects.
G. Continuity Through Change: Students will understand that matter, energy, and life respond to change and yet continue.
H. Interaction in a System: Students will understand that matter, energy, and/or life forms/units interact in systems.

Earth and Universe

I. Structure and Form: Students will understand that forms/units of matter, energy, and life can be identified by the structural characteristics of each. These can be classified according to similarities and differences.
J. Structure and Function: Students will understand that characteristics of life systems explain their functions; properties of matter and energy explain their effects.
K. Continuity Through Change: Students will understand that matter, energy, and life respond to change and yet continue.
L. Interaction in a System: Students will understand that matter, energy, and/or life forms/units interact in systems.

Grade Nine

Life and Living Things

A. Structure and Form: Students will understand that forms/units of matter, energy, and life can be identified by the structural characteristics of each. These can be classified according to similarities and differences.
B. Structure and Function: Students will understand that characteristics of life systems explain their functions; properties of matter and energy explain their effects.
C. Continuity Through Change: Students will understand that matter, energy, and life respond to change and yet continue.
D. Interaction in a System: Students will understand that matter, energy, and/or life forms/units interact in systems.

Matter and Energy

E. Structure and Form: Students will understand that forms/units of matter, energy, and life can be identified by the structural characteristics of each. These can be classified according to similarities and differences.
F. Structure and Function: Students will understand that characteristics of life systems explain their functions; properties of matter and energy explain their effects.
G. Continuity Through Change: Students will understand that matter, energy, and life respond to change and yet continue.
H. Interaction in a System: Students will understand that matter, energy, and/or life forms/units interact in systems.

Core Competencies and Key Skills for Missouri Schools
Science Grades 7 through 10.
Missouri Department of Elementary & Secondary Education,
Jefferson City, MO, January, 1990

KEY SKILL

Science 7A-1: Identify the major characteristics of organisms in each of the five kingdoms.

CONCEPT ANALYSIS

The most widely accepted form of classification of living things is currently the five kingdom system. The groups are called the Animals, Plants, Fungi, Protists, and Monerans.

The single characteristic that separates members of Monera from all the others is the fact that their cells have no nuclei. All of the bacteria are placed in this kingdom. It would be inaccurate to claim that these are simple organisms because, as a result of millions of years of evolutionary pressures, they have become astonishingly diverse.

All protists have a nucleus. Some scientists would place only single cell or colonial organisms into this group. This would exclude the algae from this group. Others claim that algae are protists, and it seems most science textbook authors would agree. Regardless, protists can move by use of flagella, cilia, amoeboid motions, or cannot move at all. Some can photosynthesize their own food; others can assume the roles of any other step in a food chain, be that herbivore, carnivore, or even decomposer. The only thing certain about the kingdom Protista is that it serves as a taxonomic bridge between the Monerans and the remaining kingdoms.

Fungi are multicellular, nucleated organisms that cannot make their own food. In fact they all gain nutrition by being parasites, or living off of dead organic matter. Plants have nuclei and are also multicellular but can make food with the availability of light. As with fungi and plants, animals are multicellular, but animals cannot carry out photosynthesis.

PROCESS SKILL ANALYSIS

Students need to be able to classify organisms into the five kingdoms based upon descriptions of the cellular structure and means of getting food energy. Monerans can be differentiated from the rest by the absence of a nucleus. For the sake of consistency, all protists are nucleated unicellular life forms and the algae are plants due to their photosynthetic ability and frequent multicellularity. Fungi are always decomposers or parasites and possess cell walls. Animals are multicellular, often mobile, non-photosynthetic organisms with no cell wall.

ASSESSMENT STRATEGIES

__Sample question:__

Match the pair of organisms with the means used to place the two into separate kingdoms:

____ 1. Fungi and Animals (C)
____ 2. Plants and Animals (D)
____ 3. Protists and Fungi (B)
____ 4. Plants and Monerans (A)

A. nucleus vs. no nucleus
B. one cell vs. many cells
C. cell walls vs. no cell walls
D. food makers vs. food consumers

Core Competencies and Key Skills for Missouri Schools
Science Grades 7 through 10.
Missouri Department of Elementary & Secondary Education,
Jefferson City, MO, January, 1990

STANDARDS

6. **Demonstrate competence in standard English.**
7. **Use language in a variety of forms.**

DESCRIPTORS	*PreK-3*	*Grades 4-5*
a) Speak, read, and write fluently in standard English.	Begin to develop fluency in speaking, reading, and writing; begin to use standard basic language conventions such as usage, structure, legible handwriting, spelling, punctuation, and capitalization.	Continue to develop fluency in speaking, reading, and writing; expand use of language conventions.
b) Combine the use of appropriate strategies and cue systems with an understanding of conventions to identify words and construct meaning from print.	Demonstrate basic understanding of alphabetic principle, sound-symbol relationships (phonics), and patterns in the context of what is read; use knowledge of phonics in conjunction with cues of semantics and structure combined with prior knowledge to construct meaning; demonstrate functional sound-symbol knowledge in composing written text.	Demonstrate a growing independence in selecting appropriate language cue systems of structure, semantics, and phonics combined with prior knowledge to read and compose increasingly more difficult print.
c) Demonstrate effective speaking strategies for formal and informal situations.	Recognize that informal and formal spoken language varies and can be adjusted to home, school, or social settings.	Demonstrate understanding that formal and informal communication vary widely and that speech, gesture, and expression can be adjusted to fit the situation.
d) Compose in a variety of genres.	Begin to recognize and incorporate basic literary devices and elements into own writing.	Compare/contrast literary devices and structures of genres; experiment by composing in a variety of genres.
e) Use forms appropriate to task.	Recognize and use various forms such as friendly letters, songs, and poetry.	Exhibit understanding of variations in writing by selecting and using forms such as business letters and news articles.

South Carolina English Language Frameworks.
South Carolina Department of Education,
Columbia, South Carolina, February, 1996

Objectives and Instructional Targets
Grade 6 Reading

DOMAIN: Reading Comprehension

Objective 1: The student will determine the meaning of words in a variety of written texts.
- Use knowledge of the meanings of prefixes and suffixes to determine word meanings
- Use context clues (e.g., synonym, antonym, definition and explanation, description, or example) to determine the meanings of unfamiliar words
- Use context clues to determine the meanings of specialized/technical terms

Objective 2: The student will identify supporting ideas in a variety of written texts.
- Recall specific facts and details that support the main idea and/or conclusion
- Arrange events in sequential order
- Follow complex directions
- Describe the setting of a story (time and place).

Objective 3: The student will summarize a variety of written texts.
- Identify the stated or paraphrased main idea of a selection
- Identify the implied main idea of a selection
- Identify the best summary of a selection

Objective 4: The student will perceive relationships and recognize outcomes in a variety of written texts.
- Understand cause and effect relationships
- Predict probable future actions and outcomes

Objective 5: The student will analyze information in a variety of written texts in order to make inferences and generalizations.
- Use graphic sources for information
- Draw logical conclusions
- Make generalizations
- Evaluate and make judgments
- Understand the feelings and emotions of characters

Objective 6: The student will recognize points of view, propaganda, and/or statements of fact and nonfact in a variety of written texts.
- Recognize the author's point of view in literary selections
- Recognize persuasive devices
- Distinguish between fact and nonfact

Stenmark, J.K. *Assessment Alternatives in Mathematics: An overview of assessment techniques that promote learning*. Regents, University of California, Berkeley, CA, 1989.

Sample Passages and Items

Notes Regarding Sample Reading Comprehension Passages and Items

The sample passages and items provided in the measurement specifications are for demonstration purposes only.

1. Actual test passages will vary in length and may be longer or shorter than the samples provided.
2. To illustrate every instructional target, more than the usual number of items per passage may appear in the Measurement Specifications.
3. Items that cue correct responses to other items will not appear on the same form of the test.
4. Sample items may not represent all eligible types of items for a particular instructional target.
5. The instructional targets that precede the sample items in these measurement specifications will not be included in actual test booklets. They appear here for reference purposes only.

Texas Assessment of Academic Skills. Texas Education Agency, Fall, 1993

Profile of Developmental Outcomes for Kindergarten Literacy and Numeracy Skills

Joan C. Hillard, Superintendent, Spreckels Union School District, Spreckels, California
Elizabeth Jones, Professor, Pacific Oaks College, Pasadena, California
Jane Meade-Roberts, Director and Owner, Power of Play Preschool, Salinas, California
San Vincente School, Soledad Union School District, Soledad, California
(Jones and Meade-Roberts 1990)

Oral language	Is nonverbal in school	Uses language to satisfy basic wants and needs	Often uses language in play and conversation with peers	Clearly describes real or imaginary situations using complex descriptive language	Speaks in whole sentences using a well-developed vocabulary
Drawing	Scribbles	Draws a face	Adds arms/legs	Adds body with arms/legs	Adds details (hair, ear, hands, etc.)
Writing	Scribbles and pretends to write	Uses letters or letter like signs to represent writing	Spontaneously writes own name including all letters	Spontaneously copies words	Can invent spelling of words using phonetic clues
Reading	Reads own name	Recognizes beginning letter of first name when written in other places	Recognizes own name, other letters and numerals.	Recognizes and reads sight words, including signs, labels, key words, teacher-created word lists and/or	Uses knowledge of letter sounds to sound out words
Attitudes toward literacy	Not yet interested in books or writing	Demonstrates focused interest in picture books	Demonstrates interest in written language (e.g., asks about or reads signs, names, words in class, labels, words in books)	Spontaneously practices writing letters and numerals	Demonstrates interest in writing correctly
Problem solving using classification	Randomly manipulates objects	Spontaneously orders by likenesses and differences	Recognizes or creates simple (AB) patterns using a variety of materials and/or symbols	Recognizes or creates complex (e.g., AABAAB) patterns using a variety of materials and/or symbols	Can classify by more than one attribute at a time (e.g., size and color)
Problem solving using numbers	Calls numerals at random	Counts by rote	Demonstrates understanding of one to one correspondence (e.g., evaluates objects accurately)	Is able to use knowledge of counting to solve real problems	Demonstrates conservation of number (e.g., understands that number of objects remains constant

Herman, J., Aschbacher, P.R., and Winters, L. *A Practical Guide to Alternative Assessment*, Association for Supervision and Curriculum Development, Alexandria, VA, 1992.

SCIENTIFIC SKILL	ASSESSMENT CRITERIA	GRADE 1	2	3	4	5
Ability to communicate scientific ideas	(a) Writes in good English; concisely, relevantly, and with the correct use of technical vocabulary.					
	(b) Can discuss scientific issues clearly and sensibly.					
	(c) Constructs suitable tables of information with correct headings and units.					
	(d) Accurately plots graphs/histograms/piecharts with correct title/ labelled axes/units/use of scale.					
	(e) Draws simple, clear, labelled diagrams, sectional if appropriate.					
	(f) Selects, devises and manipulates formulae; understands the use of standard forms and proportion/ratio; shows accuracy in the use of basic arithmetic and can use chemical formulae and equations.					
Mastery of practical work	(a) Aware of possible sources of danger and acts accordingly.					
	(b) Selects appropriate apparatus and uses it with care and dexterity.					
	(c) Is familiar with a variety of measuring devices and can use them correctly.					
	(d) Is willing to repeat readings and observations and continue with long term investigations.					
	(e) Reliably documents all results.					
Level of scientific understanding	(a) Can devise a procedure to logically investigate a particular problem using suitable apparatus and controlling/eliminating variables as necessary.					
	(b) Can determine the relevance or otherwise of results to a particular problem. Able to identify and suggest explanations for unexpected results.					
	(c) Can infer patterns from either first or second hand observations.					
	(d) Can solve novel problems using principles previously encountered.					
	(e) Shows informed concern for the social consequences of scientific endeavour, recognising the complexity of the issues involved.					
Areas of scientific knowledge encountered						

Broadfoot, P. *Introducing Profiling: A Practical Manual.* Macmillan Education, London, 1987.

Appendix 2

Extract from Frodsham High School Coordinated Science Guide Year 3 (1987/8) – pp 4–22 incl

4 Skills and Processes to be Learned and Assessed.

During the course you will improve your performance in the following skills and processes. We will assess your performance throughout the course.

1a) You will improve your knowledge of science.
 b) You will improve your understanding of science.
 c) You will learn to use your scientific knowledge.

2 You will learn to use apparatus and measuring instruments.

3 You will learn to observe carefully and record your observations accurately.

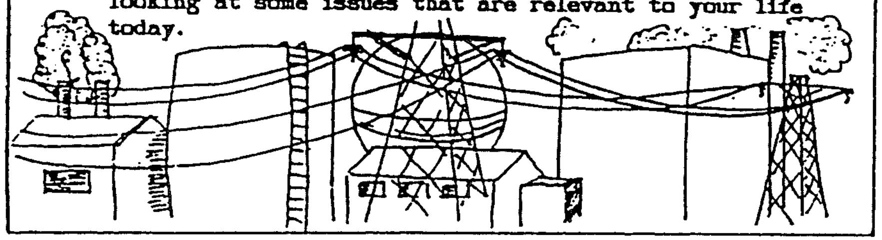
4 You will learn to plan and design experiments.

5 You will improve your communication skills, both spoken and non-spoken.

6 You will learn how to explore and investigate areas which are new to you by,
   i) practical investigations and,
   ii) data search using books, computers etc.

7 You will learn to work well with others.

8 You will see the importance of science in society by looking at some issues that are relevant to your life today.



5 How you are assessed.

First, the good news. There are no 'end of year exams' in science! However, there are several new ways of assessing your achievement. We hope that you will enjoy many of these assessments and learn to see them as a way of improving your performance.

CAN-DO TESTS.

These are simple tests to see if you can perform a stated task. For example, if you show your teacher that you can heat a substance safely, you will pass 'Can-Do Test No 16'. It's as simple as that ! A list of the Can-Do Tests used at present is given later.

SCIENCE SKILLS

Your teachers will decide the level at which you perform certain science skills. In order to help them be absolutely fair to you, they will measure how well you perform against a 'check-list'.

For example, suppose your teacher has decided to check how well you are carrying out the skill of OBSERVING. First of all, you will be given an experiment that is thought to be especially suitable to test this skill. Whilst you are carrying out the experiment, during the course of the lesson, your teacher will compare how you perform with the check list for the OBSERVING skill (See page 15). If you are noted 'taking a reading accurately', then you gain skill F1. If you are noted 'making particularly accurate observations', then you gain skill S11.

The skills can be passed at one of three levels :-

FOUNDATION, MERIT and SPECIAL.

To pass at Foundation Level it is necessary to gain any one of the Foundation Statements 1 - 5.
To pass at Merit Level it is necessary to gain any one of the Merit Statements 6 - 10.
To pass at the Special Level, it is necessary to gain any one of the Special Statements 11 - 15.

Hall, G. *Records of Achievement: Issues and Practice*. Kogan Page, London, 1989.

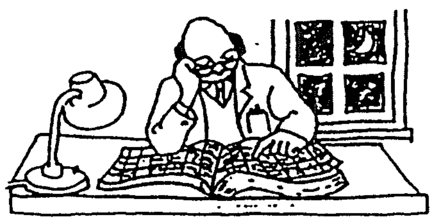
8

What happens to all these Marks ?

The results of the three types of test will be recorded both by you and your teacher. In this way you will build up a record of your achievement in Science. Your teachers will periodically review this with you and suggest ways by which you may be able to improve your performance.

Reports will be written at the end of the year based on this record of achievement. They will be much more detailed than previous reports.

Finally, all the marks you gain in years 3, 4 and 5 will count towards your GCSE grade in Science. The third year is the foundation year to the course and the marks will only make up about one sixth of your overall GCSE grade, since it is recognised that you will improve throughout the course.



Your Record of Achievement.

Can-Do Tests

9

	✓		
1.			Can use a microscope.
2.			Can make a slide.
5.			Can inoculate an agar plate.
6.			Can detect starch in food.
8.			Can use a balance.
9.			Can prepare a cutting of a plant.
10.			Can use a thermometer.
12.			Can filter a mixture.
13.			Can collect a sample of gas.
14.			Can test for & identify a gas.
16.			Can heat a substance safely.
19.			Can select a logic gate to solve a problem.
21.			Can connect a probe/sensor to a gate.
22.			Can measure accurately on any linear instrument.
23.			Can measure pulse rate.
24.			Can choose and use a Newton meter to measure force.
25.			Can identify both load and effort for any machine.

Your teacher will initial here when you can do the test.

Hall, G. *Records of Achievement: Issues and Practice.* Kogan Page, London, 1989.

GENERAL SCORING RUBRIC for OPEN-ENDED QUESTIONS
Used for Grade 12 CAP questions

Please Note: For each individual open-ended question, a rubric should be created to reflect the specific important elements of that problem. This general rubric is included only to give examples of the kinds of factors to be considered.

Recommendations: Sort papers first into three stacks: Good responses (5 or 6 points), Adequate responses (3 or 4 points), and Inadequate responses (1 or 0 points). Each of those three stacks then can be re-sorted into two stacks and marked with point values.

Demonstrated Competence

Exemplary Response . . . Rating = 6
Gives a complete response with a clear, coherent, unambiguous, and elegant explanation; includes a clear and simplified diagram; communicates effectively to the identified audience; shows understanding of the open-ended problem's mathematical ideas and processes; identifies all the important elements of the problem; may include examples and counterexamples; presents strong supporting arguments.

Competent Response . . . Rating = 5
Gives a fairly complete response with reasonably clear explanations; may include an appropriate diagram; communicates effectively to the identified audience; shows understanding of the problem's mathematical ideas and processes; identifies the most important elements of the problems; presents solid supporting arguments.

Satisfactory Response

Minor Flaws But Satisfactory . . . Rating = 4
Completes the problem satisfactorily, but the explanation may be muddled; argumentation may be incomplete; diagram may be inappropriate or unclear; understands the underlying mathematical ideas ; uses mathematical ideas effectively.

Serious Flaws But Nearly Satisfactory . ... Rating = 3
Begins the problem appropriately but may fail to complete or may omit significant parts of the problem; may fail to show full understanding of mathematical ideas and processes; may make major computational errors; may misuse or fail to use mathematical terms; response may reflect an inappropriate strategy for solving the problem.

Inadequate Response

Begins, But Fails to Complete Problem . . . Rating = 2
Explanation is not understandable; diagram may be unclear; shows no understanding of the problem situation; may make major computational errors.

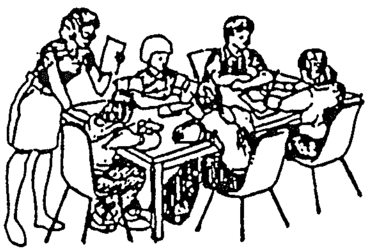
Unable to Begin Effectively . . . Rating = 1
Words do not reflect the problem; drawings misrepresent the problem situation; copies parts of the problem but without attempting a solution; fails to indicate which information is appropriate to problem.

No Attempt . . . Rating = 0

Stenmark, J.K. *Assessment Alternatives in Mathematics: An overview of assessment techniques that promote learning*. Regents, University of California, Berkeley, CA, 1989.

OBSERVATIONS (adapted from *Assessing Mathematical Understanding*, Project T.I.M.E.)

Focused Observations



Observation, to be effective and illuminating, and to enable the observer to draw some inferences about the students, should frequently be quite sharply focused. Attention to specific details may lead to unexpected insights into a student's understanding.

Students should be observed both individually and as they work in groups. The purpose of an observation may be for mathematics (How far can students count with one-to-one correspondence?) or for affective characteristics (Does this child's behavior help his learning?).

Student Learning Styles

Individuals - Do the individuals:
- consistently work alone or with others?
- try to help others? in what ways?
- succeed in asking for and getting needed help? from whom?
- stick to the task or become easily distracted?
- become actively involved in the problem?

Student Ideas

Explanations - Do the individuals:
- try to explain their organizational and mathematical ideas?
- support their arguments with evidence?
- consider seriously and use the suggestions and ideas of others?
- attempt to convince others that their own thinking is best?

Communication

Verbalization - Do the students:
- talk for self-clarification and to communicate to others?
- comfortably fill the role of both "talker" and "listener?"
- have the confidence to make a report to the whole class?
- capably represent a group consensus as well as their own ideas?
- synthesize and summarize their own or a group's thinking?

Cooperation

Cooperation - Does the group:
- divide the task among the members?
- agree on a plan or structure for tackling the task?
- take time to ensure that they all understand the task?
- use the time in a productive way?
- provide support for each member?
- think about recording?
- allow for development of leadership?

Manipulatives

Manipulatives - Individually or within the group, do the students:
- choose and use appropriate manipulatives?
- fairly share the handling of concrete objects, especially if there is one set for the group as a whole?
- sometimes use the manipulatives only visually? (e.g. count the red faces of a cube without picking it up)
- appear not to need the actual objects but be able to visualize within themselves? (e.g. can "see" the cube in her head)

Stenmark, J.K. *Assessment Alternatives in Mathematics: An overview of assessment techniques that promote learning.* Regents, University of California, Berkeley, CA, 1989.

ASKING QUESTIONS

Asking the right question is an art to be cultivated by all educators. Low-level quizzes that ask for recall or simple computation are a dime a dozen, but a good high-level open-ended question that gives students a chance to think is a treasure!

These questions might be used as teaching or "leading" questions as well as for assessment purposes. Both questions and responses may be oral, written, or demonstrated by actions taken. The questions and their responses will contribute to a climate of thoughtful reflectiveness.

Some suggestions about assessment questioning:

- Prepare a list of possible questions ahead of time, but, unless the assessment is very formal, be flexible. You may learn more by asking additional or different questions.
- Use plenty of wait time; allow students to give thoughtful answers.
- For formal assessment, leading questions and feedback are not generally used, although some assessment techniques include teaching during the examination.
- Make a written record of your observations. A checklist may or may not be appropriate.

This is a starter list. You will want to build a collection of your own good questions.

Problem Comprehension
Can students understand, define, formulate, or explain the problem or task? Can they cope with poorly defined problems?

- What is this problem about? What can you tell me about it?
- How would you interpret that?
- Would you please explain that in your own words?
- What do you know about this part?
- Do you need to define or set limits for the problem?
- Is there something that can be eliminated or that is missing?
- What assumptions do you have to make?

Approaches and Strategies
Do students have an organized approach to the problem or task? How do they record? Do they use tools (manipulatives, diagrams, graphs, calculators, computers, etc.) appropriately?

- Where could you find the needed information?
- What have you tried? What steps did you take?
- What did not work?
- How did you organize the information? Do you have a record?
- Did you have a system? a strategy? a design?
- Have you tried (tables, trees, lists, diagrams...)?
- Would it help to draw a diagram or make a sketch?
- How would it look if you used these materials?
- How would you research that?

Relationships
Do students see relationships and recognize the central idea? Do they relate the problem to similar problems previously done?

- What is the relationship of this to that?
- What is the same? What is different?
- Is there a pattern?
- Let's see if we can break it down. What would the parts be?
- What if you moved this part?
- Can you write another problem related to this one?

Flexibility
Can students vary the approach if one is not working? Do they persist? Do they try something else?

- Have you tried making a guess?
- Would another recording method work as well or better?
- What else have you tried?
- Give me another related problem. Is there an easier problem?
- Is there another way to (draw, explain, say, ...) that?

Stenmark, J.K. *Assessment Alternatives in Mathematics: An overview of assessment techniques that promote learning.* Regents, University of California, Berkeley, CA, 1989.

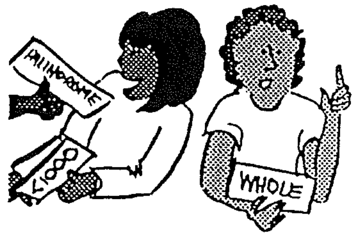
ASKING QUESTIONS (continued)

Communication
Can students describe or depict the strategies they are using? Do they articulate their thought processes? Can they display or demonstrate the problem situation?

- Would you please reword that in simpler terms?
- Could you explain what you think you know right now?
- How would you explain this process to a younger child?
- Could you write an explanation for next year's students (or some other audience) of how to do this?
- Which words were most important? Why?

Curiosity and Hypotheses
Is there evidence of conjecturing, thinking ahead, checking back?

- Can you predict what will happen?
- What was your estimate or prediction?
- How do you feel about your answer?
- What do you think comes next?
- What else would you like to know?



Equality and Equity
Do all students participate to the same degree? Is the quality of participation opportunities the same?

- Did you work together? In what way?
- Have you discussed this with your group? with others?
- Where would you go for help?
- How could you help another student without telling the answer?
- Did everybody get a fair chance to talk?

Solutions
Do students reach a result? Do they consider other possibilities?

- Is that the only possible answer?
- How would you check the steps you have taken, or your answer?
- Other than retracing your steps, how can you determine if your answers are appropriate?
- Is there anything you have overlooked?
- Is the solution reasonable, considering the context?
- How did you know you were done?

Examining Results
Can students generalize, prove their answers? Do they connect the ideas to other similar problems or to the real world?

- What made you think that was what you should do?
- Is there a real-life situation where this could be used?
- Where else would this strategy be useful?
- What other problem does this seem to lead to?
- Is there a general rule?
- How were you sure your answer was right?
- How would your method work with other problems?
- What questions does this raise for you?

Mathematical Learning
Did students use or learn some mathematics from the activitiy? Are there indications of a comprehensive curriculum?

- What were the mathematical ideas in this problem?
- What was one thing you learned (or 2 or more)?
- What are the variables in this problem? What stays constant?
- How many kinds of mathematics were used in this investigation?
- What is different about the mathematics in these two situations?
- Where would this problem fit on our mathematics chart?

Self-Assessment
Do students evaluate their own processing, actions, and progress?

- What do you need to do next?
- What are your strengths and weaknesses?
- What have you accomplished?
- Was your own group participation appropriate and helpful?
- What kind of problems are still difficult for you?

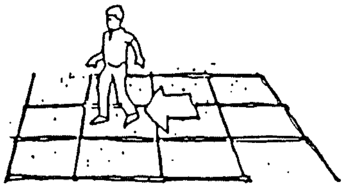
Stenmark, J.K. *Assessment Alternatives in Mathematics: An overview of assessment techniques that promote learning.* Regents, University of California, Berkeley, CA, 1989.

STUDENT SELF-ASSESSMENT

The Gift of Independent Thinking

The capability and willingness to assess their own progress and learning is one of the greatest gifts students can develop. Those who are able to review their own performance, explain the reasons for choosing the processes they used, and identify the next step have a life-long head start. Mathematical power comes with knowing how much we know and what to do to learn more.

The Role of the Teacher



This does not mean, however, that teachers abdicate responsibility. Teachers must still help students understand what is needed, provide lessons or activities to meet their needs, identify ways for students to assess what they have done, set guidelines, and ask questions that will highlight the mathematical ideas that are important. The teacher is the stage manager.

Questionnaires

A simple example of self-assessment is a questionnaire following a cooperative activity or project, asking how well the group functioned and how well the student participated. The questions can focus each student's attention on how he or she performed, and can give the teacher the opportunity to talk with the class about successes or difficulties without having to identify individual behaviors. Some typical questions:

Describe the tasks you did for the group ________________

What mathematics did you learn?____________________

How does this relate to what you have learned before?______

What could you have done to make your group work better?______________________________

What worked well in your group?____________________

What new questions did this raise?___________________

Journal Writing

Still another self-assessment is daily writing in a journal, responding to such sentence starters as:

Today in mathematics I learned____________________

When I find an answer I feel______________________

My plan for what I will do tomorrow is_______________

Of the math we've done lately, I'm most confident about ___

What I still don't understand is ____________________

Feedback from Other Students

Students can help evaluate by giving constructive comments on one another's work. Looking at others' work helps students develop their sense of standards for their own performance.

Stenmark, J.K. *Assessment Alternatives in Mathematics: An overview of assessment techniques that promote learning*. Regents, University of California, Berkeley, CA, 1989.

Vermont Mathematics Criteria

Student Self Assessment

PS 1: Understanding the Task

1	2	3	4
I didn't understand enough to get started or even make progress.	I understood enough to solve part of the problem or get part of a solution.	I understood the problem.	I identified special factors that influenced the way I approached the problem.

PS 2: How you Solved the Problem

1	2	3	4
My approach didn't work.	My approach would only let me solve part of the problem.	My approach would work for the problem.	My approach was efficient or sophisticated.

PS 3: Why- Decisions Along the Way

1	2	3	4
I had no reasons for the decisions I made.	I know I was reasoning but it's hard to see from my work.	Although I didn't clearly explain the reasons for my decisions, my work suggests reasoning was used.	I clearly explained reasons for the decisions I made along the way.

PS 4: So What - Outcomes of Activities

1	2	3	4
I solved the problem and then stopped.	I solved the problem and then made comments about something I observed in my solution.	I solved the problem and connected my solution to other math that I know OR I described a use for what I learned in the "real world."	After I solved the problem I made a general rule about the solution or I extended the solution to a more complicated situation.

C 1: Mathematical Language

1	2	3	4
I didn't use any ...age or	I used a couple of basic math ... or notations	...nt beyond ...use of ...age	I relied hea... on son...

(Permission for use is being requested: Vermont Department of Education)

National Council of Teachers of Matehmatics, *Assessment Standards for School Mathematics, Working Draft.* National Council of Teachers of Mathematics, Reston, VA, October, 1993.

Elucidation of Multiple Answers

The second and third grade tests in this category differed considerably from the tests used in fifth and sixth grade with rather different results. In second and third grades students had to give as many answers as possible out of a potentially infinite number of correct answers, for example:

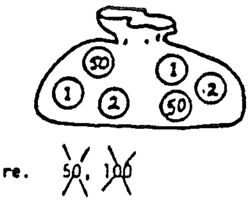
Sentences about 8, $8 = 5 + 3$
$8 = 2 \times 4$
etc.

Equations, using only these symbols: = + - x 1 2 3

eg. $2 + 2 + 2 = 2 \times 3$
$2 \times 2 = 1 + 3$
etc.

For each of the three tests in grades 2 and 3, CSMP classes produced about 6% more correct responses than Non-CSMP classes, a small but non-significant difference. Most of the difference occured at the higher ability levels.

In fifth and sixth grades, this category contained several problems, each of which had a number of correct answers (6-12) that would satisfy the given constraints. Altogether in the two years, a total of seven different kinds of problems were used and are described briefly below; in all cases students were to give as many possible correct answers as they could. The first problem is shown as it appeared on the student page; the others are shown in abbreviated form.



Rules: Take out three balls.

Add to get a total score.

Give all the possible scores. 53, ______ ___

start at zero, count by X's and reach exactly 24

pick out 3 balls, add the numbers, what total scores are possible?
(using a container with 6 balls numbered 1, 1, 2, 2, 50 and 50)

what whole numbers use only the digits 1, 2 and 3?
(no digit to be used more than once in a number)

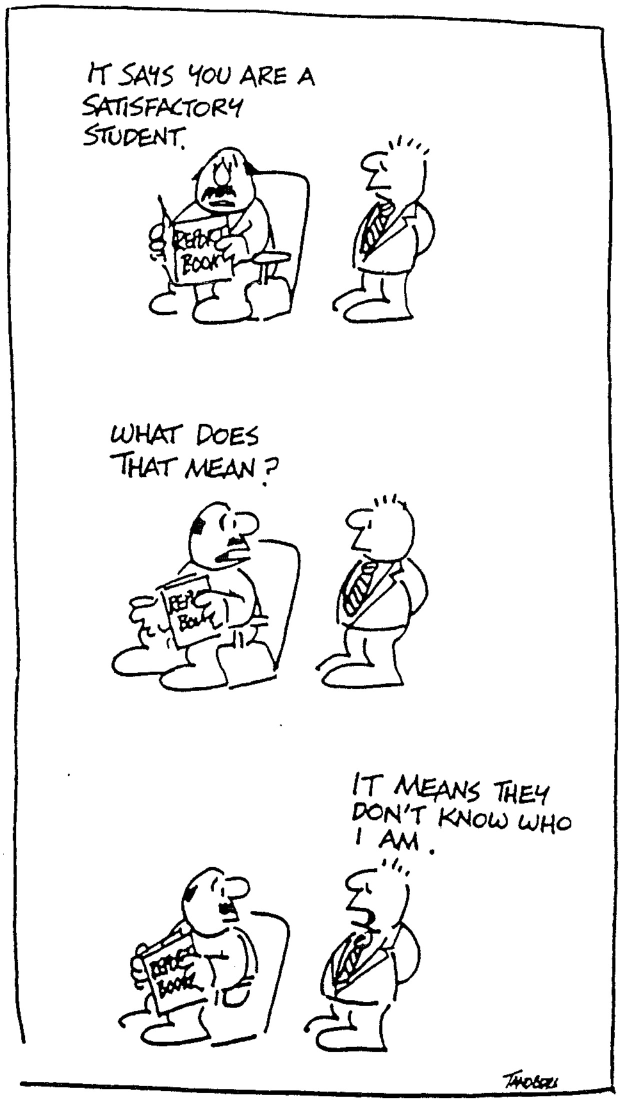
what numbers are multiples of 2, and multiples of 3 and smaller than 50?

if P + P + Q = 7, what could P and Q stand for?

what whole numbers are even numbers, divisible by 5, and < 80?

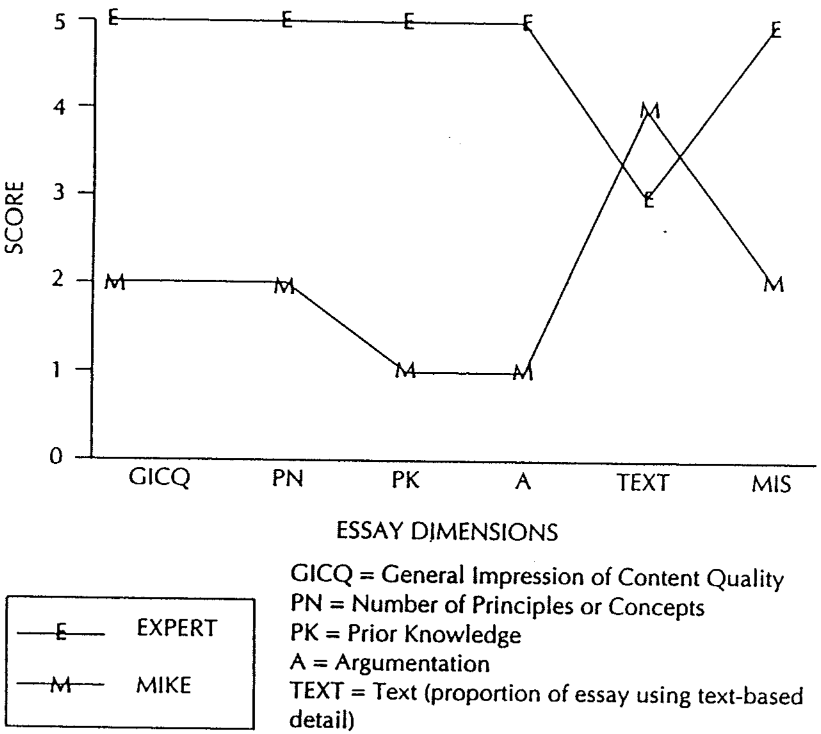
CSMP classes did much better than Non-CSMP students on these tests; the average percents correct were the same at each level, 65% for CSMP versus 53% for Non-CSMP.

Herbert, M. *Comprehensive School Mathematics Program: Final Evaluation Report,* McREL, Denver, CO, 1984.



Source: D. Suggett. *Guidelines for Descriptive Assessment*. VISE. Australia. 1985

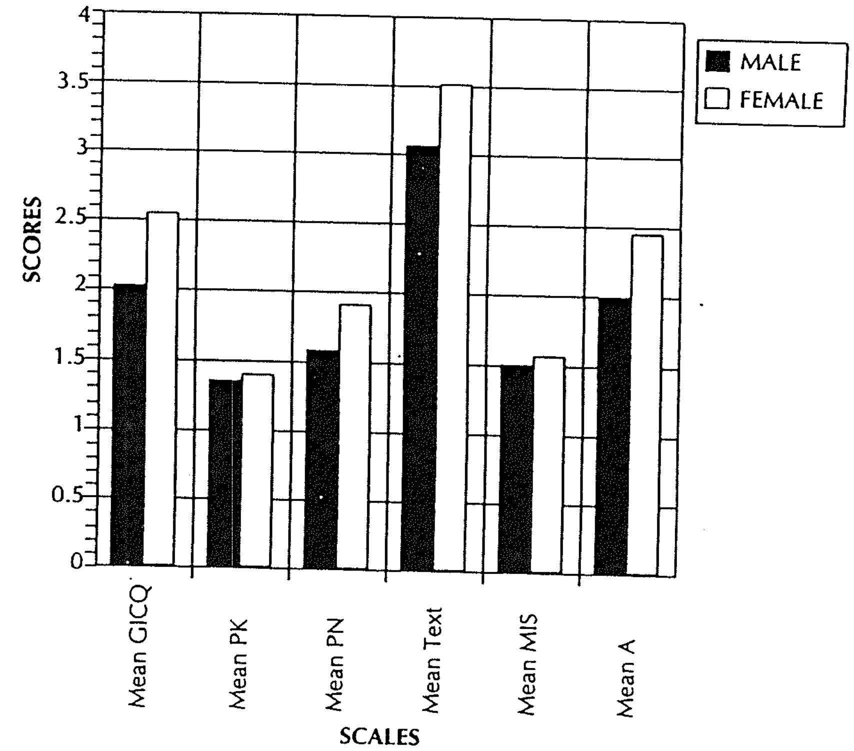
Figure 7.6
Expert and Student Score Profiles for History Essays



GICQ = General Impression of Content Quality
PN = Number of Principles or Concepts
PK = Prior Knowledge
A = Argumentation
TEXT = Text (proportion of essay using text-based detail)
MIS = Misconceptions

Adapted from Baker et al. 1992

Figure 7.7
Profiles of History Essay Performance for Boys and Girls



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EVALUATING SCHOOLS, CLASSROOMS AND STUDENTS

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Ways of Looking at Children and Schools

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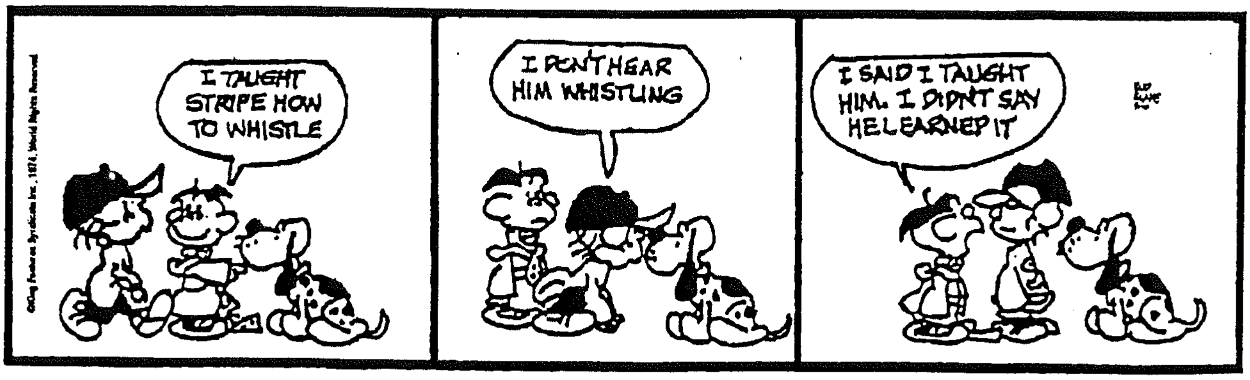

ence and are designed to give students an overview of the major milestones. Some texts encourage teachers to present demonstrations of significant scientific experiments or to conduct experiments that convey key ideas in science.

In recent years many science programs—not based on textbooks—have been developed with the goal of encouraging students to re-create scientific experiments and to share the results of those experiments with other students (9, 22). Innovative programs like Science—A Process Approach, the Individualized Science Project, the Intermediate Science Curriculum Study, Elementary Science Study, and others were planned as alternatives to conventional textbooks (38). At the elementary school level, these programs emphasize students' learning how to think as scientists do. Students were encouraged to observe, record, analyze data, and consider the meaning of the data. The goals of the innovative projects included developing students' ability to infer, to generate hypotheses, and to evaluate experiments. Not only do these science programs differ from conventional text-based courses, they also differ from one another. Just because two programs are described as innovative does not imply that they share the same goals, use the same strategies, or build the same skills. Indeed, the same program taught by two different teachers may lead to different results in students' learning. One teacher may stress students' mastery of the techniques of data collection, while another may stress the inferences students draw from the data. Different programs and different instructional approaches will yield differences in students' scientific knowledge. Different evaluation strategies may be the only way to measure what each group of students has learned. In any case, a wide range of information and skills can be evaluated. For example, among the skills science educators can measure are:

- *Acquisition of basic science facts.* Do students learn the technical terms, special vocabulary, and basic information?

- *Recall of facts.* Can students memorize and recall information?

- *Application of basic facts.* Can students use the basic facts to analyze a situation and tell how it is similar to another one they learned about? Can students read about a situation and supply missing information?

- *Understanding the generation of scientific theory and its relation to subject areas.* Can students identify an operational definition? Can

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GENOVA

IFIP WG3.1 &WG3.5 Workshop

IMA - CNR

IFIP

"Exploring Evaluation : the learner, the teacher and the school of the future"

April 1-4 , 1998

Santa Margherita (Genova) - Italy
PARK HOTEL SUISSE
Via Favale 31

Scientific Organization:
IFIP WG 3.1 and WG 3.5
IMA-CNR Genova (Italy)
D.Benzie, D.Brown, G.Chiappini, B.Cornu, A.Knierzinger, E. Lemut, , G.Marshall, B.Samways, D.Watson, D.Squires

Local Organization
IMA-CNR Genova (Italy)
(E.Lemut, G.Chiappini, R.M.Bottino, P.Forcheri, S.Greco, M.T.Molfino)

CONTENTS

TUESDAY MARCH 31

19.30 *WELKOME DRINK*

20.00 *DINNER*

WEDNESDAY APRIL 1

WG 3.1 and W3.5

09.15-09.30 Welcome - Introduction
Domestic and Organisational Arrangements

09.30-10.30 Introduction to workshop: what we wish to achieve during the three/four days
(B.Cornu & A.Knierzinger)

10.30 *COFFEE*

WG 3.1

11.00-12.30 Teacher Education - Report on findings of 3.1
(P.Nicholson)
Discussion.

WG 3.5

11.00-12.30 Design and reporting on research projects based on ICT.
Introduction (R.M.Bottino, G.Chiappini, P.Forcheri, E.Lemut, M.T.Molfino)
Discussion

12.30 *LUNCH*

WG 3.1

15.00-18.30 The Evaluation issues arising from this morning.
The way forward for the report.

16.30 - 17.00 *COFFEE*

WG 3.5

15.00-16.30 On evaluation.
Introduction (D.Benzie)
Discussion

17.00-18.30 On assessment of students.
Introduction (Gail Marshall)'
Discussion

18.30 - 20.00 *FREE TIME*
20.00 *DINNER*

THURSDAY APRIL 2

WG 3.1

09.15-10.30 The School of the Future - A UK perspective
Introduction (D. Brown)

WG 3.5

09:15-10.30 On the role of children in evaluation
Introduction (Toni Downs)
Discussion

10.30 *COFFEE*

WG 3.1

11.00-12.30 An international response
Discussion on the key issues and how they relate to other countries.

WG 3.

11.00-12.30 Elementary School Curriculum as regards evaluation
(B.Somehk)

12.30 *LUNCH*

WG 3.1 and WG 3.5

15.00-18.30 Evaluation of future schools - what are the issues?
Evaluation of future learning?

Plannig for future - School of Future events from an IFIP perspective.
Writing up brief for groups

16.30-17.00 *COFFEE*

18.30 - 20.00 *FREE TIME* ← 18.00 Annual Meeting 3.1
20.00 *DINNER*

FRIDAY APRIL 3

WG 3.1
09.15-10.30 Annual General Meeting

WG 3.5

09.15-10.30 Annual General Meetings

10.30 COFFEE

WG 3.1 & WG 3.5

11.00-12.30 Lifelong Learning. What is it? What are implications for future?
Where to from here - Vienna Conference - WWW conference activity

.

12.30-13.30 LUNCH
13.45-22.30 SOCIAL EVENT AND DINNER

SATURDAY APRIL 4

WG 3.1 & WG 3.5

09.15.10.30 Future Directions for groups - individual meetings and planning groups.

10.30-11.00 COFFEE

WG 3.1 & WG 3.5

11. 00-12.30 Issues arising from workshop - plenary.

12.30 LUNCH

DRAFT

GENOVA

II. Overview

An introduction to the nature of IFIP's involvement in education, and the issues in teacher education?

... To be edited/added to by TC3 & WG 3.1/3.5 chairs etc.

Like other IFIP 'Guidelines for Good Practice', this document does not attempt to be prescriptive, but rather, to provide the reader with an insight into current research, and practitioner views about the use of Information Technology in Teacher Education, and to suggest useful strategies for effective implementation. It is left to the reader to apply these in their particular context.

The electronic version will provide an opportunity for the variety of perspective's and issues to be increased through on-line contributions. It is hoped that this will lead to a richer set of guidelines that are truly global.

- etc ... Perhaps Tom might like to *summarise* his 1993 paper "Education & Informatics: From discovery to Maturity" here?
-

III. ICT in Education

Information and communication technologies (ICT) have become an important part of the education system of many countries during this decade. They are used in many different ways in many different curricula. They have become popular for many reasons including:

0 Facilitating new types of teaching and learning experiences and environments,

1 Supporting collaborative and exploratory learning environments,

2 Providing new tools for information creation, access and retrieval,

3 Providing educational administration functions such as record keeping, school management and currculum organisation,

4

IV. Key Issues in Information Technology in Teacher Education

An enormous challenge confronts those producing 'guidelines for good practice' in the use of information technology in education and in teacher education, or those attempting to implement effective models of use in information technology in teacher education. Clearly there is no single global solution. These guidelines attempt to provide pointers to critical issues to be addressed, successful models and ideas, and findings from the research and professional development literature.

A. Introduction

The issues that are raised in this section are those that arose out of the IFIP working conferences in Barcelona, Birmingham and Israel, and thus represent a collective, consensus view on some very complex issues. They provide a series of positions that need to be viewed from the cultural, societal and educational viewpoints of the reader.

In this brief introduction, Passey and Samways (UK) capture much of the complexity that surrounds the implementation of IT into educational practice and teacher education. The following extract from their work [, 1997 #8, p.xvii-xviii] sets the context of these guidelines:

A common agreement which emerges from any current discussion about the implementation of IT practice within teaching is that it is neither an easy thing to accomplish, nor something where there are a simple range of factors to consider.

The features of change which contribute to this complexity, but which also enable practice and implementation to be considered, can be placed into four groups:

1. *factors arise from a number of levels, and their relationships across those levels*— change is affected by the levels within the educational system, which each play a part in systemic change,
2. *perceptions of past and present successes and future potential* — change is considered worthy and necessary due to either the successes that are recorded or the potential that is considered desirable,
3. *factors which affect both failure and success*— change is affected by a range of technological, political, pragmatic, and conceptual factors which create both barriers to success and levers to success, and
4. *time* — change works within a time frame, which enables a continuous and successive wave of past reflections, present endeavours, and future ideals to be considered.

When support for change is being considered, factors come into play locally, but they are just as likely to arise from any one of the educational levels that influence teaching practice and learning requirements. For example, consider influences upon the teacher:

- at a national level, there can be an influence of *national guidelines and national curriculum requirements*;
- at a societal level, there can be an influence of *community values and commercial considerations*;
- at an institutional or school level, there can be an influence of *developmental intentions and institutional policy*;

- at the level of classroom organisation, there can be the influence of *resource deployment* upon access;
- at a teacher level, there can be an influence of *individual pedagogical focus and curriculum intentions*;
- at a pupil level, there can be an influence that home use brings to bear upon *classroom demands and expectations.*

Within this multi-layered web of influence, the need for change, and the ways in which support for change can be considered, is set within a context that is often full of potential conflicts. For example:

- whilst change is considered a desirable outcome, teachers in practice are likely *to feel supported through development* rather than through their being asked to change,
- whilst integration of new practice is a future intention, a wider perspective often suggests that *reformation or transformation* are the desirable outcomes required,
- whilst the introduction of new technologies and the practices associated with them requires a level of highly exemplified detail that teachers can understand, a great deal of detail can mean that *important and overriding philosophies and concepts can be all too easily lost* in an endeavour to satisfy the detailed skills laid down,
- whilst societal, national and international pressures determine the need for the new, *the need remains to retain the traditional* within some form of desirable balance,
- whilst there is a need to learn and integrate new practice, there is also a need to *retain a confidence and competence in teaching* based upon a recognised knowledge of previous success rather than upon an uncertainty of developing practice.

Passey and Samways ask three key questions:

1. Is it any wonder that the introduction of practices for using new technologies brings about a plethora of different solutions, which emerge as the context itself changes?

2. Is it any wonder that teachers introduce new practice in ways which range from the 'bolting on' of single activities, through insertion of a range of activities within a school year, to seamless use in lessons whenever and wherever practice seems appropriate?

3. Is it any wonder that anyone involved or considering this field and its many topics is brought back to the questions:

    - what are the purposes and philosophies of education?
    - does the use of technology lead us to question these?

In the case of teacher education, Jean Underwood (UK) raises the additional problem of '*cycles of ignorance*' arising from the historical reluctance of teacher education institutions, and teacher educators, to adopt meaningful and appropriate models of use of information technology in their courses [, 1995 #7, p.93-97].

- This results in teachers graduating with minimal computer literacy, and lacking basic competencies in the use of IT in classroom teaching and in the curriculum generally. These graduates pass on their IT deficient pedagogy to their students, thus completing the 'cycle of ignorance'.

All of the above has to be seen in the context of the wide range of challenges that confront educators in the 21st Century as globalisation and converging technologies revolutionise industry, commerce, education and society. The notions of 'school' and 'teaching' are also challenged by the continuing rapid changes in computer and communication technologies that are increasingly forming an essential component of education. They represent a wide range of challenges for those attempting to implement IT in teacher education

B. Stages in the implementation of ITTE

Much of the literature on the use of information technology in education is based around western research, and western models of education. However, there is some evidence to suggest that there are certain issues which are global, and which occur and recur in different societies and cultures. For example, if a global snapshot of the state of "IT in Teacher Education" (ITTE) had been taken today, it would have been impossible to identify any one single 'global' key issue, or one particular description of the implementation of IT in teacher education. What is currently of concern to educational policy makers, teacher educators, teachers and researchers varies geographically (for different countries) and chronologically (with the state of implementation of ITTE).

In discussing IT in both teacher education and in education generally, practitioners and researchers are frequently puzzled about why people in other countries and cultures have not learnt from their lessons. It may be that it is necessary for each country to visit the stages that other countries have already gone through in order to develop an appropriate educational culture. Seen in the light of research on institutional and educational change, this process should result in organic, rather than a systemic change. Change theory tells us that this should be more effective and long lasting than imposed change.

In describing the implementation of IT in Teacher Education, Chen Qi (CN) describes three stages which occur in many implementations of IT in teacher education, both systemic and organic, across a range of cultures [, 1995 #9]:

STAGE 1

In the early stages of implementing ITTE, many policy makers and school administrators in teacher education do not recognise the importance and implications of computer technology in education. They think that only specialist computer teachers and technicians should be involved in IT. Most teachers believe, *at least in the initial stages*, in the need for specialist computer teachers, because they do not know *why information technology is being implemented*, nor are they generally aware of its application to educational contexts. Willis argues that many of these people remain in this stage, forming what he terms a " techno-ghetto", or what Papert [Papert, 1985 #41] might describe as an extreme technocentric culture.

In this stage, the *typical* situation in a teacher education program can best be described as an isolated techno-ghetto made up of a few faculty members (the 'educational computing' instructor and perhaps one or two teaching-methods faculty), who operate in a program where the only advanced technology most students see is an overhead projector and an occasional video cassette recorder. They don't use conferencing software in their educational foundation courses; they don't learn to use multimedia in their methods courses, and they don't work with technology-using teachers in their student teaching placements. Of course, there are exceptions - the ones you read about in the journals. But the vast majority of teacher education programs fit the bleak description described above.

> This culture frequently is very resilient, and does not change over time. It reappears in various guises to constantly influence and refocuses thinking about the broader educational use of computers back to the technology. It also affects how others perceive IT in education.

Robinson (UK) emphasises that many of the common errors IT specialists make when working with colleagues could be avoided by studying the work of scholars like Rogers, Fullan, and Hall. IT specialists, for example, are often considered the mad scientists and experimenters of a group who are willing to take many chances. Many teachers are reluctant to follow the lead of an IT specialist.

STAGE 2

In Chen's second stage, followed and forced by the rapid development of new technology, the policy makers and educational administrators begin to think about how to meet the needs of the information age. They start to invest money for purchasing facilities, hardware and software, and to train teachers. They have good intentions, but have no existing exemplars for them to base their development on. They don't know *how* to change, or what the change should be directed towards. In this stage, teachers frequently try to engage with the technology *but are thwarted by a lack of support.*

Jerry Willis (USA) argues that:

> IT specialists need to learn the social technologies of change and practice them in their work. Technological change in teacher education is as much a social and organisational process as it is a technical one, perhaps more so. There is a significant body of literature on the diffusion of innovations and change in education that can support change agents.

Grant Alderson (UK) further reminds us that because IT has only had an impact on school education since the early 1980s, the majority of existing teachers do not have any personal background based on their own education (unlike other subjects) and frequently adopt the technology as presented to them. This is particularly true of teacher education institutions.

Underwood further notes that when computers first came into UK classrooms, teachers lacking IT skills accepted the software provided with their machine and diligently tried to integrate it into the classroom without an understanding of appropriate pedagogy. For example, Bleach (1986) identified a cohort of school children brought up on computer generated anagrams. The anagram moved from a peripheral activity at the end of the week or term to a core part of the English curriculum. This was palpable nonsense and teachers began to question whether the computer was really adding anything to children's educational experience.

There is great diversity in the IT experiences of students now entering initial teacher training. For the majority, this is restricted to personal word processing. It appears that it will take many more years before we get teachers who have grown up with IT in the same way as other subjects. Currently there is a culture gap, perhaps clash, between those who are natives and immigrants to the use of IT in learning.

To a certain extent, this situation may lead IT in teacher education in a roundabout way. For instance, everybody wants to be computer literate, but does not know what computer literacy involves. Teachers play an important or control role in integrating IT into schools. Usually they have some tech-phobia toward computers before they have contact with any technology. If they understand the implication of IT in education and find the technology is useful in their subjects, they will be well motivated to learn and to use IT in those subjects they teach. On the contrary, if they think something in the curriculum is unnecessary, they will do nothing for it. Willis again points out, however, that many teachers and schools systems will stay at this level of tool-like use (the influence of the techno-ghetto culture).

Underwood, in commenting on the situation in the UK comments that reliance on ageing hardware means that many schools and IT teachers are using hardware which no longer has any relevance to the workplace. Even more significant than the mismatch between education and workplace is the mismatch between hardware and new software developments. She argues that many children and students have a restricted choice of experiences because of the quality of the hardware available to them.

Whilst the former point may not concern those outside the UK's narrowly defined IT structure, the last point is crucial, and applies globally. Teacher education, in general, does not have the resources to maintain technological currency. The rapid change of technology in society has left many schools and teacher education institutions far behind. In the USA, for example, the large installed base of Apple // computers makes it difficult to justify the need for more (newer) computers when the benefit of the older technology has not necessarily been clearly demonstrated to the satisfaction of administrators.

STAGE 3

The third stage in the implementation of IT is when teachers (usually the driving force in this process) want to learn n how to use, and how to integrate, IT into the curriculum instead of just learning about the computers as machines.

Willis suggests that this stage requires a shift in teacher educators from the techno-ghetto culture to a much broader understanding of the role if IT in education which must be based on fundamental change in the use of IT in teacher education:

> If we are to prepare IT-using educators we must break out of the techno-ghetto. We must connect with the rest of the teacher education faculty and fashion mutually beneficial partnerships. We must work with teacher education leaders outside IT and we must change drastically both our professional practice and our research.

There is strong agreement about the need for teacher-educators to change their current practice and culture; essentially to develop a 'teaching by example' culture using technology integrated into initial teacher education, not initial teacher education about technology.

These stages loosely match those reported in the ACOTresearch into computer use in schools.

C. Foundations

> *It is the professional duty of teacher educators to attempt to articulate the theoretical bases for the use of IT in teacher education. Such theoretical bases will come, at least in part, from theories about how learning happens.*

Robinson's perspective's on the importance of identifying and understanding the theoretical foundations of ITTE through a focus on teaching and learning are a reminder that the essential rationale for using information technology in education is to bring about more effective teaching and better learning. For this to happen, it is essential that practitioners and administrators understand what constitutes "good learning" in IT environments, and what the factors are that can facilitate it. Additionally, it is also important to understand the human factors that impact on the ways in which teachers can be assisted and encouraged to adopt appropriate pedagogy, and to develop their personal skills and understandings through both preservice and inservice training.

IT IN TEACHERPRESERVICE EDUCATION AND PROFESSIONAL DEVELOPMENT

There are many theories of learning and many ways of learning, and all of these can probably be supported and enhanced by IT. It is not simply a matter of exploring how IT can support and enhance current practice; it is also an exploration of how IT can change the ways that teaching and learning happens. Within teacher education curricula, IT will not only support subject-teaching methodology; it also has the potential to illuminate the psychology of learning itself. IT environments might provide potential to stimulate teacher education students to reflect about learning. For example, the deliberations about Logo in the 1980s involved extensive discussions of issues about learning; could we use Logo as a way of considering Piagetian psychology as part of the study of learning theory?

How precisely can we link IT to theories of learning in both subject method teaching and educational foundations (psychology) elements of teacher education curricula? The topic is large and only partially explored. There is room for considerable research and teacher education curriculum development in this area.

ELEMENTS OF THE TEACHER EDUCATION CURRICULUM

It is important to consider the amount and type of previous IT experience that teacher education students will bring to their courses.

Inevitably students of the future will have had more experience in using IT, although this may be less true of mature entrants to the profession and clearly some student teachers, for the foreseeable future, will need to be taught the skills of using generic applications programs such as word processors, spreadsheets, and so on.

Teacher education courses should also include topics such as file and network management, software installation, etc. as appropriate, so graduates can work autonomously in situations that may have little technical support available, since the extent of such support in schools varies immensely. Issues such as confidentiality and misuse of data, copyright, viruses, etc. as appropriate at the time should also be considered. The availability of sufficient, modern equipment is critical to this process.

All student teachers will need to learn how to integrate IT into their teaching. Even students who have experience in the kinds of computer use that will facilitate the production of their term papers and assignments will lack experience of the kinds of use that would inform consideration of enhanced teaching in a particular subject area or discipline - for example, how to choose appropriate software for a particular educational activity, or evaluate the impact on students of using the technology.

Preservice teachers tend to value subject area content but have little understanding of what students can or should be taught, and for them making connections between IT and pedagogy is important. For example, use of a word processor to enhance the teaching of writing involves far more than simply knowing how to select and use the features of the word processing software. Use of a desktop publishing program to support teaching of communication skills involves more than being able to use the range of fonts and tools provided in the program. Software assessment is widely agreed to be an important part of teacher education for IT use but this should be accompanied by examples, case studies and practical work on curriculum integration of technology.

Work on technological support for differentiation in teaching, catering for many different levels and types of work in one classroom should be included. Teacher education courses should enable teachers to use IT to author their own resources.

Inclusion in teacher education courses of the use of authoring systems is thought by some to be valuable, so that classroom teachers and students might develop their own software. Skill in use of open software, or shells, into which teachers might put data or text to tailor programs or create resources for particular classroom purposes are also valued. The issue of adaptation of software for non-English speaking countries is relevant here.

Changes in teachers' roles, associated with uses of technology for learning (eg. from teacher as information source to facilitator of learning), need to be considered in teacher education courses. Inservice teachers come to courses with definite models of what teaching is but student teachers also arrive with preconceptions of what successful teaching consists of based on their own earlier school experiences. A confident willingness to evaluate and embrace change in role and performance are important attributes to develop among teachers. It should be noted that while there are significant differences between preservice and inservice teacher education in some countries, in others it is not appropriate at all to make this distinction.

TEACHER EDUCATION FACULTY DEVELOPMENT

Teacher educators should model the use of IT across the teacher education curriculum. This should include not just subject specialist tutors, but also those teaching educational foundation subjects (educational psychology, sociology, etc.). Teacher educators should make explicit to their students how and why IT has been chosen for any purpose which the student teachers encounter. Faculty therefore need to acquire the ability to use and advocate the use of IT as appropriate in their curriculum areas, demonstrating its application, discussing management issues, pedagogy and so on.

Subject specialist tutors need to be able to work with teacher education students on ways of enhancing teaching in their specialist areas using IT. This is particularly important while mentor teachers in the schools may not be using and modelling techniques of IT use during students' teaching practice. The competencies outlined in the NCET guidelines, Training Tomorrow's Teachers in Information Technology (National Council for Educational Technology, Coventry, UK, 1995) provide an appropriate general structure here. These guidelines were designed to define the IT capability which each student teacher should possess and realise in his or her school teaching. They apply equally to teacher educators and to the teacher education curriculum. (Many countries have similar statements which reflect local models and priorities.)

Each member of faculty should:

- possess basic technical capability;
- possess and promote positive attitudes to IT and its place in education;
- understand the educational potential of IT;
- model the use of IT effectively in the curriculum;
- manage IT effectively in the curriculum;
- evaluate IT use in the curriculum;
- ensure differentiation and progression.

Ultimately, it is the responsibility of specialists in curriculum areas to maintain and promote among colleagues and students an understanding of current technology in their areas, and to permit this and recent research to inform the practice and content of the teacher education curriculum. All faculty should be able to experiment and to carry out projects such as action research so that they are in a position to be innovative.

STRATEGIES

Usually little can be achieved with ICT until some curriculum change occurs to allow for its adoption.. Should this be evolution – allowing teachers to adopt ICT when,and how theysee fit, which takes time, or revolution-the imposition of curriculum on teachers? Revolution may not be appropriate since not all revolutionary ideas are beneficial. There may be new technological advances which are not appropriate to education and others which take longer to evaluate. Revolutions need revolutionaries and not all teachers are disposed to this role. Indeed, many teachers including preservice student teachers are conservative.

Change theory has already impacted on school development, and it is likely that educators have much to gain from the application of change theory to the introduction of IT in education. The use of IT prompts personal and contextual changes. Teacher educators should consider the need for preservice and practicing teachers to understand and master change processes alongside their IT development.

Strategies for IT innovation will be context specific, defined by culture, educational system and institutional organisation. However, the following elements are felt to be useful, if not vital elements of any technological innovation strategy:

- easy access to IT for both teacher educators and their students;
- information about what is available and possible;
- a culture in which sharing and collaboration are fostered
- a culture which accepts the possibility of change, shares a willingness to improve professional knowledge and performance, instils confidence in experimentation and risk taking, believes that success is possible and rewards it
- technology leaders who can inform, inspire, persuade other faculty and students and model IT use in their own teaching.

Robinson's overview of some key research issues clearly indicates how much work is required to adequately understand this complex area. This remains a major problem for educators and administrators attempting to implement IT in education and teacher education.

D. Integration issues

There is strong evidence to suggest that IT should form an integrated component of education, and, apart from informatics classes, not be the focus of the curriculum, a position congruent with Papert's concerns about technocentrism.

Cornu (Fr) provides a succinct overview of the importance of integrating IT into education, which relate to the issues raised earlier in the discussion of implementation stages [, 1995 #11]:

In most countries, education has been penetrated by computers and informatics. Schools have computers, a large number of teachers use computers and new technologies, and textbooks often have some parts devoted to new technologies. There is much research and publication about ICT in education. The development of ICT in education, however, is not as wide spread as one would have thought ten years ago, and a lot of progress has still to be made. There are two major reasons: generalisation and integration.

GENERALISATION

Much effort has been expended in order to develop hardware and software adapted to education. A lot of very interesting experiments and research have been carried out about computers in education. But computers in schools are used only by some teachers, the most enthusiastic ones, who have to spend hours and hours, nights and weekends, in order to incorporate computers in their teaching. We now need all teachers and all pupils to be able to make effective use computers in teaching and learning. We need to generalise what is now done by only some teachers and some pupils. Of course, this raises a number of questions. How can the use of new technologies in education be generalised? What are the necessary conditions? Are there helping factors? Certainly, some answers can be provided by appropriate equipment, and by appropriate teacher education; but they are not enough.

INTEGRATION

newMost of the time, technologies are most of the time just added to the curriculum, rather than forming a component of it. This approach usually fails. What is needed is a clear integration of new technologies in school, not an addition: integration in subjects, integration in teaching, integration in learning, integration in the school, integration in the profession of the teacher.

In an iterative cycle, new technologies are integrating into disciplines and more disciplines are being influenced by new technologies in an integrated way. Most significantly, some fundamental concepts are evolving and new concepts are appearing under the influence of new technologies. These new technologies and their own concepts are now involved in many disciplines.

Researchers use new technologies in almost all subjects, and this changes the nature and the methods of the work in each subject, for instance, in mathematics the concept of proof, the concept of function and the role of computations, have changed with the use of new technologies. Indeed in many subjects, new possibilities for statistics, for data processing, for simulation and experimentation, have changed the concepts and the methods through their integration in the subject. The frontiers between disciplines have also changed under the effect of new technologies, making some of them closer.

What is true for disciplines at the research or professional level is not totally true at the education level so that disciplines as they are taught do not always use new technologies. The transposition from scientific knowledge to "knowledge to be taught" has not yet taken into account new technologies, and there is a need for reflection about the integration of new technologies in "disciplines at school", and about "integrated curricula". An important question for each of our countries is "how to design integrated curricula", that is, curricula that actually integrates new technologies?

The question of integration should be raised at many different levels: disciplines, teaching, teachers, learning, education environments and teacher training. The integration of new technologies in education needs some reflection about the educational system of tomorrow, and the nature of the school of tomorrow. In every country, in every school, we need development projects, exploring the reality of integrating new technologies. It should be a matter of policy, at the national level, as well as at the school level.

> But integration must enable us to change and evolve. We must not integrate new technologies in our old habits, integrate our old strategies in new technologies, but we must change our minds, change the system, change the arena of problems. We must have a global and dynamic reflection about integrated tools and methods.

When new technologies are integrated into education, they will no longer be "visible". You do not notice what is integrated, you use it without thinking, it becomes as natural as a telephone or a watch.

V. Professional Development needs and issues.

A. Teacher Training

At this time, the predictions for the use of ICT in education have generally not been met. Although there are pockets of excellence, where information technology is playing a significant part in supporting both the learner and the teacher, on the whole there is fac a common pattern of poor or non-existent use of IT. Justifications for this state of affairs generally focus on the lack of resources. Others argue that the problem lies with the poverty of knowledge and skills in regard to ICT within the teaching profession as a whole.

GAINING MEANINGFUL ICT SKILLS AND KNOWLEDGE

On the assumption that pre-service teachers learn much of their pedagogy by apprenticeship, a productive starting point would be to raise the IT knowledge of the teacher educators The development of such skills is enshrined in the national policies on Educational IT in countries such as Australia. But what knowledge do they need to acquire?

We have seen that providing teacher educators with *personal ICT skills* does not necessarily impact on their *pedagogy* but it may be *a necessary prerequisite* to pedagogic change.

If this is the case there is a need to identify the core skills base.

However this is only a beginning. Technology is on an exponential growth path and one of the consequences of this is that the tools we now have available are increasingly specialised and subject specific.

There is a need to identify the subject specific skills base.

For all professions there is a body skills, knowledge and understandings which are unique to the profession. We need to define ICT capability for professional practitioners. This should include a critical awareness of how specific uses of IT implicitly support or promote specific epistemologies, and the implications of any one approach to IT on the overall process of learning.

In order to ensure the development of classroom practice we should identify those factors which will support effective transfer of models into the classroom. What models work and under what circumstances?

There us a need to expose teacher educators to educational uses of IT which they are unlikely to have met in their own practice or in the classroom.

The ensuing cognitive dissonance may lead to a more profound understanding and value of IT in the learning process, and increased awareness of alternative models of use.

There is a need for teacher educators to repeat that process with their students.

Teacher educators need have both a vision and a clearly articulated goals for promoting ICT. Should students have a stake in formulating those goals resulting in the known benefits that ownership and active participation always brings to the learning situation? They need to be exposed to many different implementations of IT within the classroom and to have the opportunity to experiment and evaluate those models. Will this place additional pressure on the teacher educators, or is it enough to provide effective role models for student and as a profession ensure that a strong, positive signal is transmitted to the student teachers?

There is a critical need for an appropriate and continuing level of professional development. for all educators, whether initiate, novice or expert.

Of all the knowledge domains that educators need to come to terms with, ICT is unique in that it is grounded on the rapidly changing area of technological development. All practitioners, need support in gaining new knowledge and insights and in transferring those insights to the classroom. Teacher educatirs face the challenge of a time-frame to renew their which is not mirrored in any other domain. This renewal may be an exciting and fulfilling process but for many educators it may result in stress and anxiety which we must find ways of managing.

At all levels, teacher practitioners require both adequate support mechanisms to nurture the developing capabilities and this must be a life-long professional development.

DISCONTINUITY'S AND INEQUITIES

The impact of IT is particularly pronounced discontinuities and inequities which raise educational, ethical, social and political issues.

1. There is a clear discontinuity in the level of knowledge, understanding and attitude related to IT between 'young people' and 'adults'. They, the students, are inhabitants of the new technological world whereas we, the adults, are aged tourists visiting a foreign culture. Students of the computer age think differently from we of earlier generations about the technology and with the technology. Students using IT at home will have richer information sources than their teachers, who will not only be disenfranchised by the IT, but also challenged in their own subject domains.

   Teachers may well find that their skills are seen as irrelevant by students unless they adapt to these changes and match the skills of their students. They are and will be challenged to develop new curricula and assessments as these changes take place. The degree and pace of change are not as yet known but it is probable that in IT we have the tool to deliver Illich's deschooled society

2. A second discontinuity is evident in the lack of a shared understanding and common goals between the hardware and software developers and the education community. This is a very significant gap in that the industry, fuelled by market imperatives coupled with the thirst for technology of young people, are together beginning to drive the education agenda. This is further compounded by the techno-romantic view of IT held by many parents, and indeed policy makers, who have been beguiled by the industry's marketing.

There is a pressing need for the education community to take back the responsibility for education. While it is easy to asses the value for money of current technological we do not know whether they will prove to be of value in terms of learning.

We have already alluded to the inequalities the in hardware and software resources. While these certainly exist and are of concern, the distribution of that inequity is not a simple matter of rich developed countries versus the third world, or indeed leafy suburb versus inner city tower block. All countries show a similar pattern of affluence and want. Although we believe that the distribution of resources into areas of need should be a priority goal, The inequality of the distribution is likely to remain as more fortunate areas continue to acquire the latest hardware and software.

Equality may be an impossible goal but a minimum workable level of provision should be available to all.

Equity issues including those related issues of gender and ability may prove significant as gate-keepers to the good life.

CONCLUSIONS

At this time we would suggest that there are a number of imperatives that we can not ignore.

1. Teacher Education must be renewed with a focus on the integrated use of ICT.The most cost effective strategy to achieve this would be to target teacher educators' IT capabilities. To affect this goal requires identifying good practice and develop strategies for disseminating that practice across the profession. A policy of mandatory IT competencies is strongly recommended.
2. It is critical to refocus the education agenda from the market place and once again focus on the learner and the learning process.
3. As a corollary to 2 (above) we need to establish how technology impacts on this technological generation? In so doing we there is a need to re-evaluate the role of the school in this new technological society.
4. Finally, although resource issues remain a concern, a minimum level of provision of IT resources for all would seem to be a realistic if less than ideal goal.

SUGGESTIONS FOR DEVELOPMENT

The following key issues of research, professional development and of political and social action would form a useful basis for future discussions.

Our initial focus here is on the learner and we would ask how technology impacts on attitudes, knowledge and understanding technological generation? Are those attitudes and understandings a product of home or school exposure to technology? Can we identify learning processes and products in such interactions and, if we can are they transient phenomena or sustainable changes. To identify long-term changes requires significant funding from government and related sources. How can we press the case for a realistic time scale for key, fundamental research?

A change of focus to the educational system would raise issues about the future nature of schooling and the development of a curriculum relevant to a new age. Alongside these questions we would wish to discuss who should set the education agenda? Can software imperialism ever be a good thing and, whether beneficial or not, is it too late to halt the shift in power to the industrialists taking place?

If we are arguing for life-long professional development, how would this be funded and how would it be affected? The establishment of support networks within the educational community though the technology would seem a good starting point. How is such a resource to be established and, more importantly, sustained?

B. Pathways for change.

Teachers are expected to change their practice in order to incorporate IT effectively in their teaching and learning. They are expected to be innovative in a system which frequently expects teachers to be resistant to personal or systemic change. Where change is actively promoted, it is expected to take place in an environment which differs vastly from industry and commerce where managers can spend up to 30% of their time in training for technological change within the organisation. Developing support for professional change requires that the external view of education is transformed so that teachers can be regarded as true professionals in the same way as, for example, doctors with an equal expectation of lifelong learning and significant ongoing professional development. The operating theatre of today is very different from that of a century ago. Can we say the same of today's classrooms (Papert, 1993)?

It is important to clarify the systemic imperatives that drive large scale change. For example, what is the rationale for change? Is it focused on the attainment of educational goals or is it driven by economic considerations? Because educational change is affected by the political climate, the goals frequently change, as does the notion of "what is appropriate" at any time. This can be a serious impediment to long term change, or even to ensuring success in the short term. A clear understanding of the nature and purpose of change is essential to breaking the cycle of ignorance (Underwood, 1996). Teacher education programs need to be based on the mechanisms of change, not just on the educational milestones commonly set by the policy makers or on the perceived immediate needs of teachers.

Change is inhibited because there is no clear conceptual model of the educational benefits of IT. This leads to alternative perspective's, sometimes unrealistic, about classroom practice and appropriate resource levels. There is also a common perception that professional development is not needed because it is assumed that normal classroom pedagogy can be transferred directly to the technological medium. Teacher change is gradual and requires a change of knowledge, teaching strategies and beliefs as well as the acquisition of IT skills (Fullan, 1991).

Change Models

Teachers must also have a firm understanding of the nature of change and how to bring it about effectively. Change often arises because the current situation is problematic and uncomfortable. Tension and conflict may already exist. Certainly as change begins, it is likely that these uncomfortable states will occur (Schon, 1971). Teachers must be prepared to accept that change is uncomfortable: it will involve doubt and uncertainty, risk taking and conflict. Teachers and policy makers should understand the distinct phases of structured change. Change should begin with the identification of teacher needs. Teachers might have existing needs which IT can help satisfy. New needs may also be created by external agencies or by the existence of technology itself. The Concerns Based Adoption Model of Change or CBAM (Louacks and Hall, 1977) offers a structured way of conceiving the origins and process of change.

Not all needs can be satisfied with IT. The technology might not be appropriate or the barriers against using it might be too great. Realistic goal setting is therefore required. Problem solving change models help focus on the need to identify realistic and appropriate goals, paying attention also to potential barriers and catalysts of the intended change. Force field analysis techniques can be useful as a way of assessing the strength of opposition and obstructive barriers.

Attention must also be paid to the likely and expected implications and outcomes of innovation (Consequence Projection) and to the strength and desirability of these (Significance Evaluation). (For further discussion of these techniques see Eraut, 1991). Sometimes, the intended change is just not worth the effort to be expended. A successful change agent is one who also knows when not to attempt change.

The implementation phase requires a sound perception of who and what will be required to effect the change and where and when the intended actions will take place. While the end result of educational change must ultimately be new behaviour in the classroom, in order to get there teachers will require changes in their knowledge, skills and attitudes.

In the remainder of this section, three models arepresented which, while not change models in the formal sense, help teachers and teacher educators to define and redeftine their practices in using IT

THE NEED FOR PEDAGOGICAL AND DIDACTIC MODELS.

To make effective change requires certain knowledge, skills and attitudes to be an effective change agent. Having clear visual and conceptual models can help teachers and others to understand and implement change, and to analyse their changing pedagogy over time. It is important to analyse the entities that change and to identify the intended versus implemented aspects of change. There is a need to link change originating from research with developmental change arising from practice. Research evidence needs to be presented in a forum that is accessible to teachers, and visual models facilitate this. Also, models help in examining innovative processes and experiments already undertaken in pedagogy and outside education. (IT is not a special case.)

THE OREN MODEL OF IT PEDAGOGY

The OREN model is useful in identifying the nature of current pedagogical practice, and for considering ways to include IT in learning environments. Educational software embodies a model of learning while other "tool" packages require teachers to impose their own teaching style or model of student learning upon them. To maximise the potential of IT, teachers must look for a match between what IT can do and what they want to happen in educational terms within the classroom. Such an examination might very well prompt teachers to look for new ways of teaching and learning. The Oren model can help teachers and school systems to identify the conditions that need to be changed - by identifying what their current practice is, what factors affect it, and what the change means in regard to those items.

The Oren model in figure 1 indicates pedagogical positions that teachers adopt in relation to IT. This model simplifies some of the more complex aspects of change by focusing on four types of learning environments. Each represents a particular way of teaching with, or without IT.

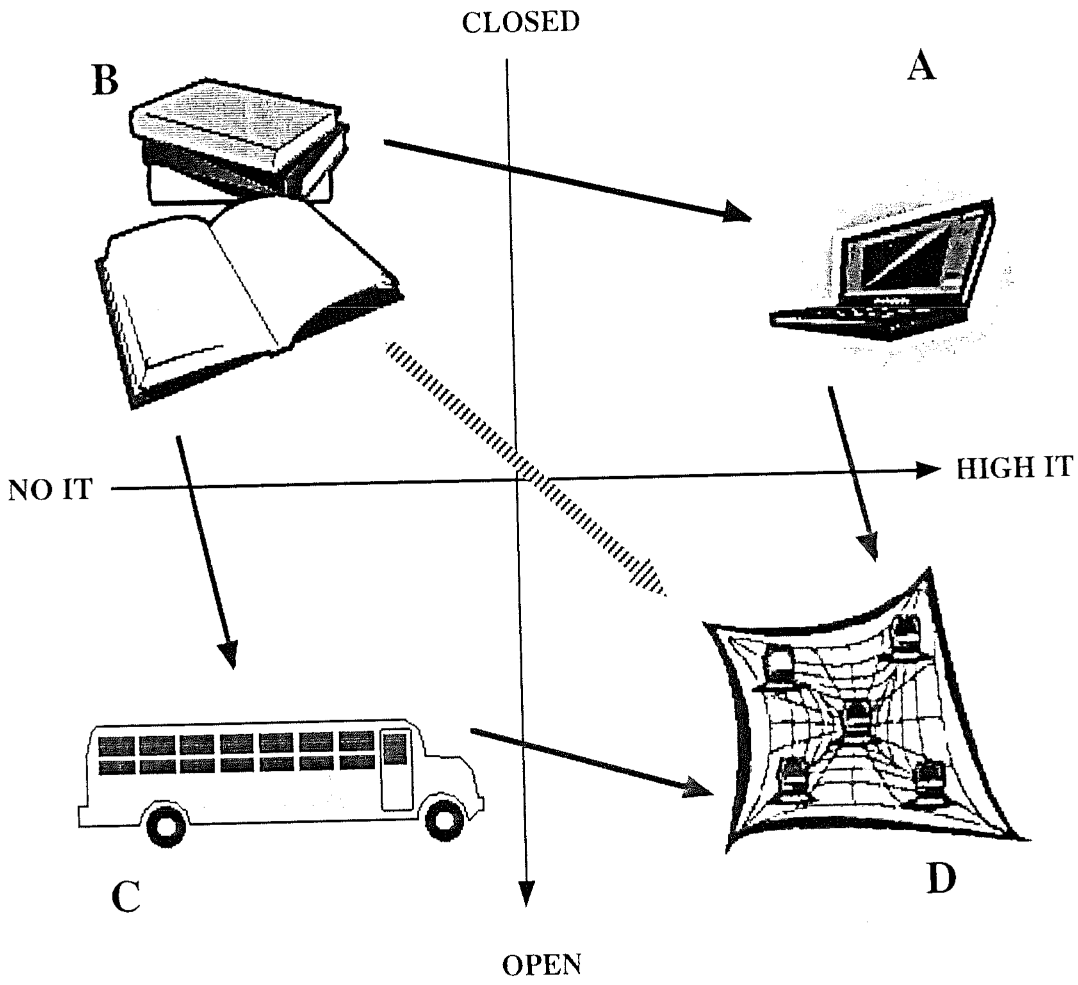

Figure 1: The Oren model - pathways for classroom change with IT

The horizontal axis represents the use of IT in the classroom. The vertical axis represents the way that the teacher conducts classes. A 'closed' classroom is defined as one in which the students are working on well defined, closed tasks in a traditional classroom with no IT usage. An 'open' classroom is likewise a traditional classroom, but one in which the students are working on open-ended activities which require research or collaboration on the part of the students. These environments are explained by referring to the pedagogy of a teacher located in each quadrant.

Teacher A
A teacher operating at A would conduct a traditional classroom in which the students use IT to access CD-ROMs and other resources for particular closed activities. For example, a science experiment graphed in a spreadsheet, or a poem or story written using a word processor. The classroom is similar in nature to that of teacher B, but includes the use of IT a tool for producing reports, and accessing school-based electronic resources. External resources such as library catalogues may also be

accessed by electronic communications. These activities have a clear and specific purpose.

Teacher B
A teacher working at B, would provide structured learning tasks for the students, who would work individually (not in a group) and rely primarily on learning and teaching resources within the school. IT would not feature in the classroom.

Teacher C
A teacher operating at C, would have similar ways of working as the teacher at B, but in addition to the resources existing in the school, would use resources existing in the wider community.. Group activities and collaborative projects would be common classroom structures. IT would not feature in the classroom.

Teacher D
Some teachers for example might be high IT users who teach in an open-ended way, and would therefore appear in quadrant D. Change is perceived in such a way that teachers at B are often directed towards D, when a move to C or A might be more appropriate.

CONDITIONS FOR CHANGE

The change process is represented by a shift on this Oren model, and there are factors which drive this process. But before teachers can move across the map the change process needs a stimulus to occur.

The Kiryat model in Figure 1 depicts the common expectation that teachers at "B" - traditional classrooms with a conservative curriculum model and no use of IT, are expected to move directly to "D" (the grey arrow), where they are expected to become users of IT in an open-ended curriculum. This requires a change in two dimensions of the model - IT use and pedagogy. This may simply prove too difficult for some to be able to make the change. Perhaps a better way to conceptualise what is expected of teachers is to consider the pathways the model depicts.

For example, some teachers may simply want to make the transition B-A to incorporate IT into their traditional classroom setting, where it acts more as "tool" than a transformative agent. This transition of course is a valid one, and many teachers may wish to stay at that point. Equally, others may follow the transition A-D, where the IT facilitates a change in pedagogy based on pre-existing experience with IT in traditional environments. Similarly the transition B-C-D reflects a situation where a non-IT user adopts a more open curriculum and at some later stage recognises the potential that IT has in developing that type of curriculum to provide new types of learning experiences. The key point of the model is that simultaneous change in too many dimensions may be too hard, and so fail.

Change	Meaning
B to D	This is a major shift in two modes at one time. It implies a shift in both pedagogy and in IT usage. It is often too hard to make this concurrent shift in two variables. There are therefore two different pathways in which more gradual change might occur.
B to A	This would represent a IT being used as a tool within a traditional classroom model, for example the use of a graph plotter instead of plotting graphs by hand.

A to D	This represents a change in pedagogy in which classroom activities move into more open ended, problem solving modes and exploratory learning instead of completing the traditional classroom exercise
B to C	This involves a shift towards problem solving and open ended activities in a traditional classroom environment.
C to D	involves the uptake of IT to enhance the activities in an open ended classroom.

Table 1: Transitions in the Oren change model

Note that it is not necessary that Position D is always attained - some teachers can remain in A and be successful teachers using IT.

A further aspect of the model above is that it could also be used to map the use of IT in a curriculum, with teachers or schools mapping their activities over a year onto the model to see in which areas they fall. This would potentially be a useful tool to help a reflective practitioner to consider their pedagogy.

THE KIRYAT ORGANISATIONAL MODEL

The Kiryat model (Figure 2) is a mapping of time, place, group size as they relate to classroom practice. It focuses on the organisational nature of the learning environment — traditional classroom, distance education etc. This three-dimensional model can also help teachers to conceive of where their practice is located, and what things might be changed to move to a new place in the model. Like the Oren model, this could also be used as the basis of a chronological mapping of practice, so that the diversity of their teaching models could be tracked over time.

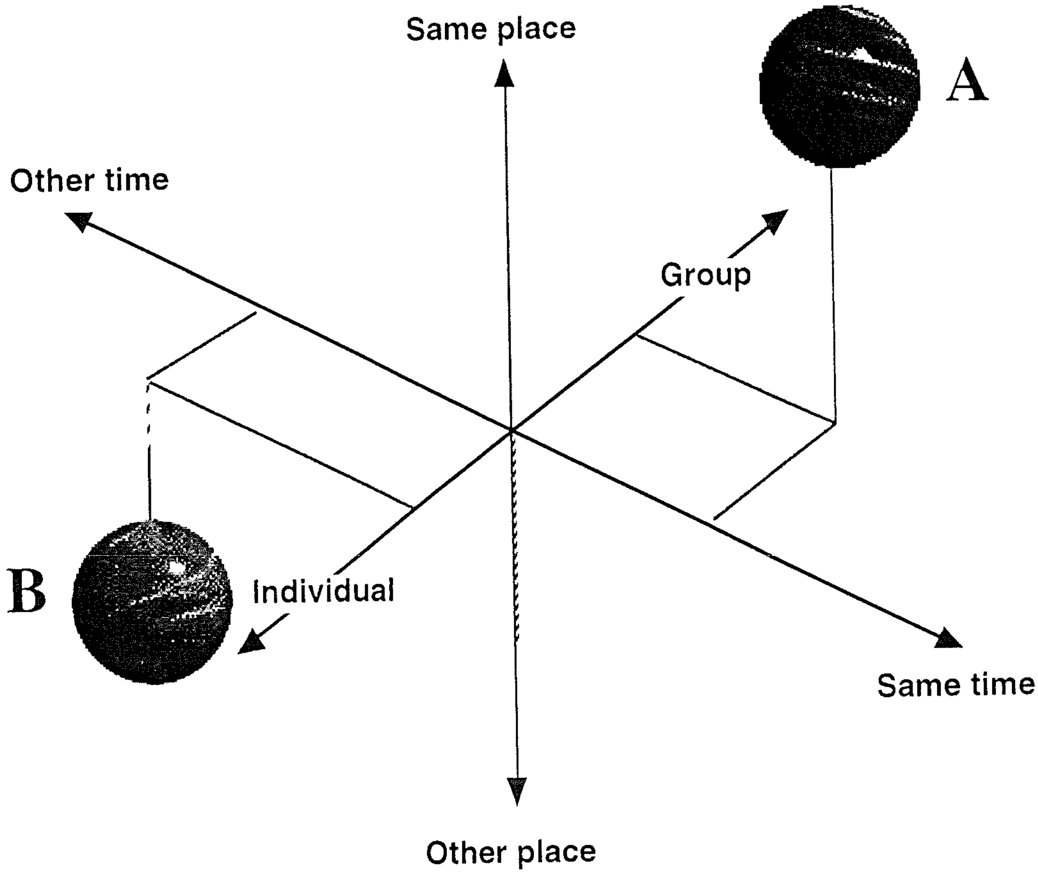

Figure 2: The Kiryat pedagogical model

In this model, various kinds of educational settings are depicted. For example, the circle "A" in figure 1 represents a traditional classroom - all of the students learning together in the same place at the same time. Circle "B" represents a "distance-education" student - somewhere else, learning alone, at some other time. In the design of this model, it was assumed that mapping educational goals onto this pedagogical model would lead to further insights into the curriculum and delivery processes being examined as part of planned change processes.

THE ANAVIM GRID

In addition to the information provided by the Oren and Kiryat models. there was seen to be a need to fully understand the responsibilities of the stakeholders in the change process corresponding to educational principle components - exactly who was going to do what, and why? The sample Anavim grid (Table 2) is an example of the type of analysis that is seen to be an essential component of analysing change processes. The grid's headings are to be altered by each user to suit their needs and are not mean to be definitive. The crosses indicate who assumes responsibility for the elements of change in the left hand column.

Unlike the previous two models, this grid is not directly focused on the teachers pedagogy or instructional context, but rather seeks to determine who is responsible for particular aspects of both currrent and future learning environments. This provides a clear picture of what may be changed to produce particular outcomes in the use of IT.

Such information is now becoming more commonly collected in Unviersituies as part of the strategic planning and quality assurnace processes. It is necessary for Faculty's of Education to access, monitor, and use this information in implementing effectve programs of IT in teacher eduation.

Stakeholders/Partners/Actors

DOMAINS	Student	Parent	Teacher	Principal	IT Person	Board	Authority
LEARNING							
• Basic skills							
• Learning Styles	X		X	X		X	
TEACHING							
• Professional development			X	X			
• Curriculum development			X	X		X	X
• Program development			X	X		X	X
• Materials development			X				
IT infrastructure							
• Resources		X	X		X		X
• Networking		X	X	X	X	X	X
ORGANISATION							
• Funding				X		X	X
• Communication			X	X			
EXTERNAL							
• Community expectations		X	X	X	X	X	X
• Employer expectations		X					
• Vocational pre-requisites		X					
• Policy Framework						X	X
• Technological evolution	X	X	X	X	X	X	X

Table 2: A sample Anavim grid for stakeholder analysis

PERSONAL CHALLENGES

Monitoring and evaluation are essential components of any change effort. Goal setting should be accompanied by attention to the way in which the attainment of the goal can be assessed. Performance indicators offer one form of measurement. Observation techniques, surveys and other forms of data collection and analysis can be borrowed from research methodology for the purpose.

Who undertakes the evaluation and for what purpose are other important questions to consider. (For further discussion of this subject see the report of Focus Group 3 elsewhere in this book.) The evaluation process should be seen as a start as well as a conclusion to any change effort. Change should be a continuous cycle of improvement built upon the ability to be a reflective practitioner. Action research offers a good model of the iterative process involved (see Elliott, 1981).

Change requires recognition of the fact that it cannot take place in isolation and requires co-operation and collaboration with others. Other individuals, institutions and whole systems need to change if individuals are to change. Individuals therefore need to be effective organisational change agents too. This is why the models presented in this section are so important - they provide the individual educator with a means of analysing and reflecting on their current and possible future pedagogy.

GENOVA

VP → Boston → 2002

What every literate citizen should know about computers and information technology

(A proposal suggested by Viera K. Proulx)

Recently in the USA the National Research Council and the Computer Science and Telecommunications Board commissioned a study entitled **What Every Literate Citizen Should Know About Computers and Information Technology.** The study group exploring this topic and working on the report consists of some of the top computer science researchers, such as Alfred Aho, Jeffrey Ullman, Larry Snyder, Andries Van Dam, Allen B. Tucker. To get a wide input form a number of knowledgeable people they requested position statements from those interested in this study. In January 1998 the study group held a two day workshop aimed at receiving input from those who submitted position papers. At the end, all participants were asked to compile a list of ten key topics.

I participated in this workshop and found the discussion very enlightening and interesting. The question "what should we teach in high schools about computers and why?" has long been of great interest to me.

I attach a copy of the original call for comments and position statements, as well as my position statement and my "Top Ten" list. I would like to see the WG3.1 organize a conference that would explore similar issues at the global level.

I would be willing to act as a liaison with the NRC/CSTB study group and report back on their work, as well as help in organizing such conference.

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March 31, 1998

see http://www2.nas.edu/cstbweb/549a.html

What Everyone Should Know About Information Technology

A first meeting was held August 19-20, including planning for a workshop to be held on January 14-15, 1998 in Irvine, California. Key issues include identifying and presenting enough of the right ideas and effecting communication of those ideas by computing and communications experts to others involved in education of undergraduates (and possibly advanced high school students).

Recognizing that the definition of "information technology literacy" is subject to many different points of view, the committee seeks input from the community at large. A major part of the project's task is to develop a consensus for the appropriate definitions of "everyone", "know", and "information technology".

The committee responsible for this project is chaired by Larry Snyder, professor of computer science and engineering at the University of Washington -- the full membership of the committee can be found by clicking here ->

In order to collect input from the wider community, the committee has developed a number of questions for which it hopes to generate a broad response. These questions are primarily directed at different stakeholders, as described below. However, you should feel free to comment on any set of questions.

Questions for Computer and Communications Scientists and Engineers
Questions for Employers and Labor Professionals
Questions for K-12 and Post-Secondary Educators
Questions for Librarians
Questions for Commercial and Business Information Technologists (e.g., MIS support, Chief Information Officers)

The committee invites you to submit your answers to these questions in the form of a short position paper (5 pages or less); in addition, please identify your field of expertise and your institutional affiliation. All responses will be considered by the committee. In addition, respondents may be invited to participate in a workshop to be held in Irvine, California on January 14-15, 1998 whose purpose is to discuss answers to these and other related questions. Or, they may be invited to revise their position paper for inclusion in the committee's final report.

Note added January 29, 1998:
For more information on the proceedings of the January 14-15 Workshop in IT Literacy, click here ->

DEADLINES:

· December 15, 1997, for those who wish to be considered for participation in the workshop.

· February 1, 1998 for those who wish their input to be considered by the committee.

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Last Updated on 02/18/98

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What Everyone Should Know About Information Technology

Lawrence Snyder, *Chair*
University of Washington

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1 --What should information technology-literate individuals be prepared to do in the future? What sorts of lifelong personal, career, and policy decisions should such individuals be prepared to make? Why?

(By "IT literacy", we mean not only an IT-literate person's ability to effectively use computers and other information technology tools, but also his or her understanding of how such technology works, and the role of such technology in society.)

2 -- What should all high school graduates/students know about information technology to achieve information technology literacy? Please describe each element of this knowledge (e.g., how to troubleshoot a software problem or how to make an informed decision about a public policy decision that involve information technology) and briefly say why you believe this is important. For each element, suggest what about it you believe should be taught at what grade levels.

3 -- What learning experiences do students need to achieve the technological literacy described in answer to question 2? ("Learning experiences" can include both in-school and out-of-school activities.) Please be specific, using examples from your own teaching if possible.

4 -- What technological environment (computers, networks, software, resources, etc.) do precollege teachers need to teach technological literacy? What is the minimum technological environment needed today? What is the ideal technological environment needed today? Why? Please describe the relationship of the elements you provided in Question 2 to the nature of this environment. (For example, what kinds of computers or connections to the Internet are minimally adequate?)

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Computer Science and Telecommunications Board
National Research Council

Position Statement for the Study Group:
What Every literate Citizen Should Know About Computers and Information Technology

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In defining what every literate citizen should know about computers and information technology we focus on the concepts, skills, and ideas that should be introduced and explored in precollege years. The core of this position statement is the answer to the second question "What should all high school graduates/students know...". The answer to this question outlines a curriculum framework for the pre-college years. The answers to the remaining questions are based on this curriculum.

1. **What should information technology literate individuals be prepared to do in the future? What sort of lifelong personal, career, and policy decisions should such individuals be prepared to make? Why?**

   A technology literate individuals should be prepared to use the computer as a tool in nearly all aspects of personal and professional life. Specifically, they should be able to use a computer to:
   - record data and information
   - access and search for data and information
   - process and analyze data and information
   - communicate with others using computer-based communication modes

   The ability to use a computer for these tasks does not come just from drill in certain computer manipulation skills. The next section describes the concepts behind these uses of computers that all high school graduates should understand. The knowledge of the fundamental concepts behind computer systems and their use provides a framework for literate use of computers in a variety of tasks and for understanding the many societal implications of computer use and misuse.

   The knowledge of these fundamental computer science concepts will also provide a basis for making decisions regarding any particular use of computers. We will return to this topic after we discuss the fundamental concepts.

1. **What should all high school graduates/students know about information technology to achieve information technology literacy? (elements of knowledge, why this is important, what about it should be taught at what grade levels)**

   I believe the following concepts are fundamental and should be understood by all information literate individuals:

   Representation of information
   Processing of information: the concept of algorithms
   Encoding of algorithms: the concept of languages
   Management of complex systems: the concepts behind OS and networks
   Sense of scale
   In addition, intertwined throughout all these topics are the issues of societal impact.

A. Representation of Information

- o elements of knowledge:

All information literate individuals should understand that there are (at least) two levels of representation of information. On the basic level is the encoding of specific information in the form of bits and bytes so that the data can be stored in the computer memory, transmitted through the networks, or stored in more permanent medium such as CD-ROM or a computer disk. Here we learn about encoding of an image as a sequence of pixel colors, storage of real number values as truncated floating point numbers, characters encoded in ASCII or Unicode. This is important, in order to understand that any memory location can represent any type of data.

At the higher level are the concepts of encoding the human knowledge about a particular phenomenon in form of data that can be stored in a computer, or conversely, representing the data stored in a computer in a form that is best understood by a human. Some of the basic examples here are an array of data values represented as charts for the human reader, pixel data displayed as an image.

Additionally, information literate individuals should understand that different pieces of data can be linked together through indices, search tables, data bases and other mechanisms - to simplify the access to a particular piece of information.

- o why this is important:

By understanding how data and information is stored in a computer and retrieved at a later date, information literate individuals will better appreciate both the power of computer stored information and the potential for misuse - either intentional or inadvertent. They will also understand the limitations of current computers, the need for further research, and the need for careful policy decisions related to the use of computer based information.

- o what about it should be taught at what grade levels:

Pupils in the first grade learn about the number system and continue learning formal arithmetic throughout the elementary grades. They also learn the alphabet and how to use it to read and write. It would be easy to include other methods for representing numbers, and letters throughout the elementary grades. Paint by numbers pictures are nice examples of pixel based image representation. Various secret alphabets have captured imaginations of children for ages.

In the middle and high school the topics related to encoding and decoding information provide a great setting for practicing problem solving skills and enhance student's understanding of the standard topics in algebra and geometry.

Additionally, students learning to use a database should also discuss how the information is stored and how the chosen database design impacts how difficult it is to answer some of the queries.

B. Processing of information: the concept of algorithm

- o elements of knowledge:

All information literate individuals need to understand that any computer operation is controlled by the program written by humans. They need to know that each program represents instructions for carrying out a sequence of steps needed to perform a specific task.

To understand the difficulty of the task of writing programs, all information literate individuals should also know what are some of the basic building blocks of algorithms (decision, repetition, calculation, recursion) and understand the basic problem solving strategies (stepwise refinement, iteration, divide and conquer, backtracking, hierarchical decomposition) used in algorithm design. They should be able to follow (perform) a simple algorithm, be able to write a simple algorithm (possibly expressed in pseudocode or precise English statements).

- why this is important:

Computers would be useless if they only stored information. The key ingredient that turns a computer from a data storage device into a useful tool is its ability to process data and information according to a given algorithm - i.e., by following a prescribed process. Only by understanding that anything a computer does is a result of human decision to make the computer behave that way, will the information literate individuals truly appreciate the power of the computer and (again) the danger of its misuse.

There is another reason why this topic is essential. Not only do computers follow algorithms - a large number of other processes that an individual performs daily fall into the realm of algorithms. Problem solving techniques that form the foundation of algorithms creation, implementation, testing, and evaluation, can be employed to face the ordinary challenges of everyday work. By looking at basic components of algorithms - repetition, decision, decomposition into simpler parts, we are giving students tools for understanding the nature of controlled processes in general.

- what about it should be taught at what grade levels:

Anybody who played a card game or a board game knows what an algorithm is. In the early grades pupils often need to learn to follow directions - in effect acting out a given algorithm. Programming a Logo turtle has been a common way of introducing algorithms into elementary school curriculum.

In later years, students should understand reasonably well what an algorithm is - see examples not only from the computer science domain, but also as they appear in the context of sciences, and social sciences. They should learn the basic problem solving techniques - iteration/repetition, decision, divide and conquer, recursion, backtracking, and hierarchical decomposition. All of these can be presented in the context of playing games, solving mazes, solving real life problems, and simple computational problems.

When learning to work with spreadsheet, students may try to deduce the underlying algorithms, discuss possible ways of organizing the program to make it do all what it does, etc. Students may even write simple macros to add functionality to the spreadsheet - thus learning a little bit of programming while becoming more competent users of a valuable tool.

C. Encoding of algorithms: the concept of languages

- elements of knowledge:

All information literate individuals need to understand that an algorithm needs to be expressed in a language that both the writer of the algorithm and the performer of the algorithm understand. They should be aware of the variety of languages we encounter in our daily lives, and understand the need for the precise definition of the syntax and semantics of a programming language. They should also be aware of the fact that a compiler is needed to translate the program into simpler instructions that the computer is designed to carry out.

Another important topic that arises from studying languages is the issue of naming objects in an unambiguous manner. All information literate individuals need to understand the principles behind naming and scoping, especially in hierarchically organized name spaces (computer directories, URL's, e-mail addresses, etc.).

- why this is important:

Computer science is not the only field of human endeavor that uses specialized languages. Chemistry, medicine, stock market, cooking, knitting, dance, and music all have their own languages and grammars used to communicate ideas and descriptions of processes. By understanding the nature of languages, grammars, the syntax to define well-formed sentences and the semantics to assign meaning to phrases, students will be able to express their ideas in a clear and coherent manner and will learn to extract precise meaning from sentences written by others.

Naming and name spaces permeate our daily computer use. By understanding how the names are designed, what is the meaning of the various components of a name, and how the names are looked up and connected to the appropriate object, will help in remembering names, in making decisions about assigning new names to objects, and in participating in decision making on matters related to name spaces.

- what about it should be taught at what grade levels:

Kids love special languages. They may know about pictorial directions for finding a fire exit, for leaving an airplane, they may have used various forms of pig-Latin, they may be studying a foreign language. They are well aware of the need for naming objects - indeed, learning names of objects is one of their major goals in the early years.

In upper grades students should become aware of the number of different languages that people use and get the first glimpse of the principles behind the definition and implementation of a formal language. They can learn about simple formal grammars (for example for arithmetic expressions), see what strings or expressions are legal, what are the restrictions, etc.

They should learn about the different name spaces used in the world of computers, use them in communicating on the Internet, and when dealing with their own directory name space.

D. Management of complex systems: the concepts behind OS and networks

- elements of knowledge:

All information literate individuals need to understand that a computer is a complex system managed by a special program named operating system. They should understand the role of the memory, the processor, the storage devices, the communication devices, and the protocols for controlling them. They should also understand the principle of layered systems - these are encountered daily in many different contexts. The key issues here are the design of interfaces and understanding of the competing forces of information hiding and information giving.
We should include here also topics that relate to management of networks - protocols, reiteration of the naming concept, routing, bandwidth, etc.

- why this is important:

The world around us is very complex. To perform any task requires the ability to identify the level at which we need to operate and to define carefully the inputs (initial assumptions, the available resources or data, the control signals that will select among several options) and the outputs (the resulting product, data, or action). The ability to comprehend and be able to manage complex tasks is crucial in today's world.

Networks support communication. By understanding the underlying principles one is better equipped to be concerned about the dangers, be aware of the limitations, and be ready to explore the full range of options available.

- **what about it should be taught at what grade levels:**

In early grades pupils should learn how computer works from a conceptual point of view. They should understand a bit about 'who is responding' to their mouse clicks, possibly by imitating a computer in role playing games.

In middle school and high school students working with computers should take time to learn about the various components, their role, and how the interaction between the various parts is controlled by the operating system. While using the computer for communication and 'library search' students should also become aware of the need for network protocols, routing algorithms, search engines, etc.

E. Sense of scale

- elements of knowledge:

Computers allow us to deal with problems at a scale nearly impossible to comprehend. It is important

that all information literate individuals have a sense of scale - i.e., understand what is the rate of growth, "how fast is fast, how slow is slow" and how two different rates of growth compare.
All information literate individuals need to understand why some algorithms cannot be performed in any reasonable time and why other algorithms arrive at the answer very fast. (Examples such as binary search contrasted with towers of Hanoi bring the point home very quickly.) They should also be aware of the fact that not all problems can be solved by a computer (the halting problem).

- why this is important:

Some people think computers can do everything. Others wonder why do we need faster and bigger computers all the time. By understanding the complexity of computation, these questions are answered clearly.

Again, the issue of rate of growth, and the growth of complexity is not restricted to the world of computing. The demographics, the economy, the use of natural resources - all use the rate of growth arguments to predict future behavior and to assess past events.

- what about it should be taught at what grade levels:

The two examples mentioned above are comprehensible to upper elementary grade students. More examples of similar sort, as well as a bit of time for reflection and comparison of different rates of growth can be done in middle and high school. High school students also encounter the issues related to the rate of growth in other subjects (sciences and social sciences).

F. Societal impact

By understanding the topics outlined above an information literate individuals will be able to make informed decisions about many issues related to the use of computers in daily lives and policy decisions regarding computing.

1. What learning experiences do students need to achieve the technological literacy described above?

Some of what has been described above. In addition, students should be using computers as tools for science projects, English papers, social studies, mathematics exploration, and language study - as appropriate. The learning of the computer science concepts should serve to provide background and context for competent use of computers.

1. What technological environment...?

Most of what has been described in 2. can be learned without ever touching a computer. So, minimally, we need skilled and knowledgeable teachers.

At the other end, the computer environment should resemble the computer environment in the world of work - ubiquitous access to the needed tool for all students at all times would be ideal.

Minimally, every classroom should have several computers with the access to the Internet, and software appropriate for the subject matter - as well as a teacher skilled in its use. There should be a way to display to the whole class what is happening on the computer screen - without doing excessive setup.

The ten key things every literate citizen should know about computers and information technology

(A list of topics suggested by Viera K. Proulx)

1. The concept of stored data stored program computer:
Computer executes a program written by humans that uses data supplied by the user and produces results. Both the program and the data is stored in the memory.

2. Representation of data in the computer:
The data can be encoded, displayed, and 'inputted' in a number of different ways, representing a vast multitude of the types of information.

3. The data can be organized into entities:
Files, data bases, html pages linked through the WWW - all allowing easier and more controlled access to the desired information

4. The concept of language:
A formal, carefully defined language is used to communicate with a computer - at the low level something like machine code or instructions keyed into a calculator, at the high level menu driven selections, querry languages, with 'higher level programming languages' in between.

5. The concepts behind managing and defining complex systems:
Information hiding and information giving, abstraction and encapsulation, layered systems.

6. The concept of scale and order of growth:
How fast is fast, how slow is slow, what in intractable, what cannot be computed, why do we care.

7. Varied examples of uses of computers in the world around us:
Commerce, information depository, medical applications, weather modeling (and other types of modeling), image processing, simulations and forecasting, control systems, virtual reality based training systems, exploration and experimentation for sciences and math, etc.

8. Ability to use basic applications and access computer based information - in the context of meaningful tasks:
Word processors, spreadsheets, e-mail and other means of communication, presentation software, web searching and authoring, image and sound processing applications.

9. Understanding of the impact of computing on todays society:
Privacy, security, safety, intellectual property ownership and rights, medical risks, the issue of inequity.

10. Ability to critically assess computer-generated results:
The nature of web documents, the potential inaccuracy of computation, the risks of programmer errors, faulty design.