Guidelines for Good Practice

Tom J. van Weert (ed.)

Integration of Information Technology into Secondary Education
Main Issues and Perspectives

Ferran Ruiz i Tarragó

(February 1993)

IFIP

IFIP Technical Committee for Education TC-3
Working group on Secondary School Education WG 3.1
International Federation for Information Processing

Guidelines for Good Practice

Tom J. van Weert (ed.)

Integration of Information Technology into Secondary Education
Main Issues and Perspectives

Ferran Ruiz i Tarragó

(February 1993)

IFIP

IFIP Technical Committee for Education TC-3
Working group on Secondary School Education WG 3.1
International Federation for Information Processing

PRICE: 5$ (U. S.)

Integration of Information Technology into Education-Main Issues and Perspectives.

ISBN 84-600-8520-1

Ferran Ruiz i Tarragó

IFIP Technical Committee for Education TC3
Working group on Secondary School Education WG 3.1
International Federation for Information Processing

Guidelines for Good Practice
IFIP Working Group 3.1

Tom J. van Weert (ed.)
School of Informatics, University of Nijmegen, The Netherlands

Integration of Information Technology into Secondary Education Main Issues and Perspectives

Ferran Ruiz i Tarragó
Generalitat de Catalunya, Departament d'Ensenyament, Programa d'Informàtica Educativa (PIE), Barcelona, Spain

Index

Guidelines for Good Practice
IFIP Working Group 3.1

Tom J. van Weert (ed.)
School of Informatics, University of Nijmegen, The Netherlands

Integration of Information Technology into Secondary Education
Main Issues and Perspectives

Ferran Ruiz i Tarragó
Generalitat de Catalunya, Departament d'Ensenyament, Programa d'Informàtica Educativa (PIE), Barcelona, Spain

Guidelines for Good Practice

A tradition of good practice

This paper on **"Integration of Information Technology into Secondary Education"** is the second in a planned set of Guidelines for Good Practice sponsored by the International Federation for Information Processing (IFIP) Working Group 3.1 on Secondary Education. In combination with IFIP's Working Group 3.1 Guidelines for Good Practice "Informatics Education in Secondary Schools" [Tayl91] this paper gives an overview of the whole field of informatics in secondary education. Further papers in the IFIP WG 3.1 Guideline series will provide a more in-depth treatment of specific topics.

This series is another in the continuing efforts of the IFIP Working Group 3.1 over the past two decades to provide leadership internationally in informatics education. A similar paper series, first released in 1971, paved the way for the movement of informatics education in secondary schools [IFIP71], [IFIP72], [IFIP75].

State of the art

This first series outlined the state of the art of a rapidly developing field prior to the advent of the small, portable microcomputer which has made secondary informatics education a real possibility for all students. The new series is designed to have the same global impact, reflecting decades of change and advances in informatics education world-wide and giving the present state of the art. It should provide assistance for those modern pioneers who are now addressing the problem of informatics education in the secondary classroom.

IFIP Working Group 3.1

IFIP Working Group 3.1 (est. 1966): Informatics Education at the Secondary Level

Working Group 3.1 works under IFIP Technical Committee 3 on Education; its work is devoted to informatics at the secondary level (age 11 to 18).

The mission of the Working Group is to provide, from an international viewpoint, a forward look on the development and impact of informatics, and its applications, in secondary education.

IFIP Working Group 3.1: General Aims

The Working Group aims to develop effective communication among its members who come from many different countries. It seeks to gather the most recent information on research and practice related to informatics at the secondary level. This information is communicated through the Working Group's communication network, through working conferences and workshops. In this way the information is developed into a collective expertise shared by the members of the Working Group. On the basis of this collective expertise prospective ideas about development and impact of informatics at the secondary education level are formed. The collective expertise is shared with others through open conferences, seminars and workshops, through publications (mostly published by Elsevier) and consultancy.

IFIP Working Group 3.1: Scope

The themes of the work done within IFIP WG 3.1 concern all aspects of computers in secondary schools. Among the themes are:

- informatics education (or computer science education),
- informatics in other subjects,
- computer tools for teachers,
- computers as pedagogical tools in teaching and learning,
- influences of these tools on the contents and methods of teaching and learning,
- computer tools for management and administration of secondary schools,
- computers and teacher education,
- distance learning.

Collective expertise to be shared

IFIP Working Group 3.1 tries to further the professional work of each of its members, to identify problems, questions, experiences and solutions. The group is aware of the fact that there is in general no unique solution, and that specific circumstances of people and countries must be taken into account. Essential is that the collective expertise helps each member to continuously have top level, state of the art information, to share experience and prospective ideas, to be aware of different solutions to problems and different points of view.

IFIP WG 3.1 tries to share its collective expertise through documents, up to now mainly the proceedings of working group conferences and topical documents in which accumulated knowledge and experience is synthesized.

How to reach IFIP WG 3.1

IFIP Working Group 3.1 may be reached through the IFIP Secretariat, 16 Place Longemalle, CH-1204 Geneva, Switzerland, tel: 41 (22) 282649, fax: 41 (22) 7812322, E-mail: ifip@cgeuge51 (bitnet).

Goals of this paper on "Integration of Information Technology into Secondary Education"

This paper aims to consider and survey the main issues in the use of informatics tools in secondary education, with special attention for the problems with integration of Information Technology into education.

Many of the considerations in this paper could be broadened to also encompass primary education. However it is outside the scope of this paper to elaborate on this age group. This paper also does not analyse the details of the specific use of Information Technology in different academic subjects.

This survey provides a "breadth-first" approach and discusses all topics which we consider as vital to the eventual integration of Information Technology into secondary education. After reading this document the reader should have a good perspective of all the key aspects, as well as more in-depth insight into some of these aspects. All topics discussed reference international sources to enable readers to get additional information.

In combination with IFIP's Working Group 3.1 Guidelines for Good Practice "Informatics Education in Secondary Schools" [Tayl91] this paper gives an overview of the whole field of informatics in secondary education. Further papers in the IFIP WG 3.1 Guideline series will provide a more in-depth treatment of specific topics.

Target groups

This paper is meant for teachers, educational managers and administrators, educationalists, civil servants and politicians, and parents who have to deal with the integration of Information Technology into secondary education in its different stages.

Some terms used in this paper

In this paper the following terms are used with the indicated meaning:

elementary education:	general education for pupils in the age range of 4 to 12 years of age,
secondary education:	general education for pupils in the age range of 11 to 18 years of age,
college education:	secondary education with a vocational focus,
informatics education:	education about informatics,
vocational education:	education focused on specific job environments,
informatics:	the science concerned with information processing,
Information Technology:	informatics technology combined with other technologies, such as video technology and telecommunication technology.

Abstract

This paper deals mainly with issues of and perspectives on educational uses of Information Technology which are beyond the introductory stages. The main topics which are discussed in this paper, are:

- curricula,
- human factors (teacher development and student skills),
- school organization,
- hardware and software.

Other topics which are discussed in less detail, are:

- funding,
- tele-communication,
- equity.

The rationale for the discussion of the topics mentioned is to be found in the following:

(1) Changes in society force the curriculum to change,

(2) Integration of Information Technology into secondary education is a complex activity, which should take into account human, organizational and management factors, as well as curricular concerns,

(3) Developments are influenced by a strong technology push in several areas, such as multi-media. But account should be taken of the fact that hardware and software, the basic materials for the desired learning situations, are not always available or adequate.

(4) Any technology-based development can only survive with a solid basis of funding. To create such a basis is a significant problem for schools and educational systems.

(5) The social awareness of equity problems brings into the discussion issues like gender, special needs, and socio-economical status in relation to opportunities offered by Information Technology.

Acknowledgement

Early discussions directing the development of this paper were held during the IFIP WG 3.1 Working Conference on "The impact of informatics on the organization of education" in Santa Barbara (California) in August 1991. The paper took its final form before the IFIP'92 Congress in Madrid, Spain, during a very stimulating two day meeting of IFIP WG 3.1 members: Bob Aiken (USA), Bernard Cornu (F), Bernard Dumont (F), Immo Kerner (D), Raymon Morel (CH), Brian Samways (GB), David Tinsley (GB), Peter Waker (SA), Deryn Watson (GB), Tom van Weert (NL, chairman) and the author (E). The author expresses heartfelt thanks to all of them and also expresses thanks for the comments of Joaquim Castellsaguer, Magda Bruin and Jacques Hebenstreit. Special mention must be made of the support received from Mr. Martí Vergés, director of the Programa d'Informàtica Educativa (PIE) of the Generalitat de Catalunya.

Integration of Information Technology into Secondary Education
Main Issues and Perspectives

Introduction

A rapidly changing perception

The rapid development of Information Technology (IT) and the permeation of its use in almost any field of human activity have brought about profound cultural and social changes which require corresponding changes in educational systems and in students skills. Secondary education is in the process of redefining itself in order to cope with society's needs, at the same time exploring and implementing IT applications for any type of pedagogical advantage which can be derived from the technology.

Facilitated by the advent of microcomputers, Information Technology now has a real and still increasing presence in secondary schools and is the focus of many educational activities and research. Perception of the applicability and potential of IT has been evolving continuously. Experiences gained, the astounding technical advances, the economical availability, all have been factors in this evolution.

A push towards integration

The educational process is essentially that of learning by the learner, supported by teachers and an educational environment. Learners come to this environment from different backgrounds and with different experiences. Information Technology is already affecting the family at home through a consumer market of appliances, current media and modern toys in which IT is fully integrated. Many learners, and their parents, will expect teachers and schools to increase, and not destroy, the confidence in this integrated technology which they have built from experiences at home. Uses of Information Technology may be found in schools, even in the same school, in many stages of development: exploration, pioneering, introduction. But at this moment full integration of IT in education is nowhere to be found. Still, learner's expectations will have to be met if the learning process is to take place effectively. In many cases this will imply full integration of Information Technology into education. This paper focuses on the problems which will have to be faced when dealing with this process of integration.

Integration as a major innovation

It is clear that in this process of change much will depend on the background and the skills of the teachers. It is not realistic to expect all teachers to be up to date, enthusiastic or confident in applying Information Technology in their work. Some will fear Information Technology and will need help in building confidence and making the most of the IT potential in an environment where students tend to be more IT proficient than their teachers.

It is believed that Information Technology in secondary education is here to stay, but that the full integration of IT is a generic innovation, which will deeply influence the functioning of schools and the learning of students. This integration is tied to a major educational change which will only be fully realized in the long run.

I Information technology in secondary education: an overview

I.1 The cultural and social dimension of IT

Introduction

Several, slightly different, definitions of Information Technology (IT) can be found in the technical literature. Basically all of them state that IT (1) is aimed at the processing and communication of information, (2) is the confluence of informatics with other technologies, communication technologies and to some extent video technologies, (3) has many social, economic and individual implications, and (4) is based on micro-electronics.

Because of the social, economic and individual implications the role of IT in education is to be more than that of a "teaching machine" or a micro-electronics discipline with some "social" add-ons. The rationale for IT in education is to be found at two cultural levels:

- the global culture in society, which is becoming symbiotic with information and Information Technology,
- the culture of the students, embodied in values, abilities, knowledge and skills, which has to integrate the fundamental life skills required for a technological society [Bish84].

The role of information

Throughout history there is an on-going cultural process in which information is separated from the human being to lead its own life. This process of "the objectivisation of information" (see Masuda [Masu80]), has progressed in three major stages. In the first phase the alphabet was invented: information was written down. This major cultural step was based on the "simple" technology of the bodkin and clay, and later ink, quill, and paper. For the first time information could be stored in an objective form, independent of oral tradition.

A second major step forward for humanity in the process of objectivisation of information was the invention by Gutenberg of movable type fonts. The printing press made possible the reproduction of information by machine, accelerating its production and allowing its distribution on a large scale. The printing press is the technological milestone which separates the Middle Ages from modern time. Unprecedented cultural, economic and social developments have taken place because of this far reaching change in the sphere of information.

Now, in the second half of the 20th century, a third major step is taken with the invention of the computer. This machine, with capabilities for memorization, calculation and control, is able to process and communicate information. According to Masuda, this is the third stage in the objectivisation of information - to be traced back to the invention of photography and of punched cards in the 19th century. Information now has an objective importance of its own, and its automatic processing expands and amplifies man's intellectual capabilities. The focus is the concept of Information Technology, including information systems, methodologies to process information of almost any type (texts, numbers, graphics, sounds, video and electric signals) and communication systems.

Changing society

The rapid development of Information Technology brings about world-wide changes which are sufficiently important to be designated as "the second industrial revolution". Modern day society, "the information society", is in the middle of an economic process which does not only result in an increase in importance of the service sector, but above all in a move of work away from production of material goods to production of more intangible things, like information and communication. According to Naisbitt [Nais82] the major change in the nature of employment is to be found in the steady increment of the percentage of the population involved in information processing and service oriented activities.

Conclusion

To sum it all up, there is growing a universal culture, based on information and its automatic processing and communication, which defines the context in which the impact of IT on learning and teaching processes, on student competencies and skills, and on the educational system has to be analyzed. Integration of IT into secondary education requires action in all these areas. In the next two sections the demands on students and on the educational system are considered in more detail.

I.2 Demands on students related to IT

Student competence

Children and young people follow a usually long period of formal education in primary and secondary schools, in the expectation that this enables them to participate in society, contributing to its development in a creative and positive way. The global results of the schooling period for the student should be:

- A set of basic values, i.e. a collection of subjective basic attitudes which underpin and guide his or her personal behaviour. Important basic values relate to: honesty, solidarity, personal initiative, mental curiosity, self-organization, motivation, self-discipline, responsibility and perseverance. One can easily imagine that an attitude of lifelong learning may be based on those basic values.
- A set of key capabilities, i.e. cognitive, thinking and interaction capabilities (higher order thinking skills). Thinking is an imprecise term, but here it is meant to denote creative and critical thinking, logical reasoning, problem solving and decision making [Macl91]. Some examples of these key capabilities are: being aware of and understanding problems, relating a problem to a wider context, using of sources of information, working in a creative way and collaborating with other people.
- A base of general knowledge, i.e. domain-specific information in traditional curriculum subjects, and basic background knowledge in languages, sciences, arts, general culture, informatics, etc.
- A specific skill base, ranging from hand writing to using a word processor, from solving of first degree equations to plotting of a graph, from searching for information in a encyclopaedia to using a computer index. Information skills [Marl81] are specific skills which because of their informational nature will be needed in most of the student's activities.

Need for a changing student competence

Societies moving through constant technological change are in demand of educated people with high-level skills, higher than ever before. This is clearly stated by the Organization for European Co-operation and Development [OECD88]: "In the manufacturing sector, requirements are shifting towards multi-skilled roles, teamwork and conceptual skills. In the service sector the focus is much the same, but with additional emphasis on customer and communication skills." Conceptual and communication skills are central skills in an increasingly knowledge-intensive economy. Secondary education should allow students to develop such high-level skills. Vocational education, traditionally aimed at teaching more job specific skills, is being redefined to cope with the stated economic needs. The separation between general secondary education and vocational education is becoming progressively less clear because of this need for values, key capabilities and general knowledge on which basis specific skills may be developed when needed.

Information skills are much needed because in a service and technological society people have to manage and process information on a daily basis, in volumes and at rates never experienced before. Whether as creators or as receivers of information, the professional life and private activities of most of today's students will be based upon their capabilities to acquire, analyse, select, reject, store, formulate, communicate and access information. Furthermore, many of the student's values, abilities, knowledge and skills will be related to IT, Information Technology "being by far the most pervasive and influential (of technologies) in terms of its impact across all sectors of the economy, including the service industries" [OECD88].

Integration of IT competence

The facts which were discussed before, strongly support the integration of an IT competence into the set of competencies of the educated person. This IT competence, sometimes narrowly conceived as "computer literacy" or "computer awareness", may be developed during the schooling period under the condition that an effective policy for integration is available. In terms of student competence, the IT competence is a learning outcome which the Department of Education in Northern-Ireland [DENI89] defines as: "a knowledge and understanding of appropriate uses of Information Technology, with the corresponding ability to apply it sensibly and with confidence in the areas of communication, information handling, modelling, measurement and control; and a recognition of the effects which Information Technology can and will have on themselves, other individuals, organizations and society".

A new pedagogical approach

The pedagogical approach to development of such an integrated competence by the student may be called a "pedagogy of information", which in Gwyn's words [Gwyn86] is "a pedagogy increasingly directed towards an understanding of information and its manipulation", instead of a pedagogy aiming at the acquisition and retention of factual knowledge. Because information skills may be transferred to other disciplines, the student's development of this competence is the basis for further mastery and integration of concepts and procedures of knowledge acquisition and information processing throughout professional life. The IT competence acquired in secondary education may constitute a firm basis for continual updating of professional skills, which are bound to change as a result of the evolution of technology.

Although some of the aspects of IT-competence may be developed or strengthened by appropriate teaching, the key methodologies for the successful development of IT-competence seem to be active and interactive learning taking advantage of the interactivity of the modern computer. Specifically, project work, problem solving and collaborative learning in an environment rich in information and IT resources should be stressed as main methodologies in the secondary education curriculum. New evaluation and assessment methods are needed for these methodologies. These methodologies require a positive student attitude, because only personal involvement and motivation enable students to develop high level intellectual skills.

I.3 Demands on educational systems related to IT

Different forms of adaptation of educational systems

With society changing to an information society, educational systems react in different ways taking up the challenge to adapt themselves to new roles. On the one hand there are educational systems which adapt themselves in a utilitarian and immediate way to the needs of the labour market and the economy. "Educational reform is currently high on the agenda of most western industrialized countries. ... the impetus for this reform has been motivated primarily by an extremely narrow focus on the need to upgrade the educational system so that industry can meet the demands of increasing global competitiveness" [Cumm90]. Re adaptation of curricula to the needs of vocational education, adequate provision of equipment and slight modifications in the teacher-centred pedagogy is all that is needed in this case.

On the other hand there are educational systems which aim to make students conscious of their informational and technological environment and to encourage flexible and rational behaviour (in working activities, in personal and spare time activities and in social activities). These systems do not just react to immediate economic needs, but take account of significant cultural, scientific and environmental realities. The approach in these systems is to develop thinking and IT competencies of the students, rather than specialised skills related to specific jobs or tasks. This places great demands on schools and success seems much more difficult to achieve because of a school tradition of "success in adapting to Tayloristic work organization in factories and offices with a regime that denied enthusiasm, autonomy and problem-solving to the majority of pupils"

[OECD88]. Another difficulty in this approach is that it requires a global interplay of all agents of education. If adopted, one could say that this approach shows the school system not to lag behind in social transition.

"Living" technology at school

In spite of the difficulties with the approach last mentioned there is the fact that in most countries primary and at least a part of secondary education are compulsory from an age of 5/6 years to 16 years or higher. This is an enormous asset, because this immense resource of social space and time, permits IT to be introduced, learned and practised in school as an integral part of educational activity. In other words, the extent of compulsory education makes possible, if properly organized and managed, to "live" technology at school, and that constitutes a unique opportunity for acquiring values, abilities, knowledge and skills, in a well-balanced and durable way. Living a technological culture at school, properly integrated into an innovative curriculum which stresses initiative, problem-solving and an open mind to change, could be the most fundamental way to respond to the demand for new capabilities of the work force and the demand for lifelong and transferable skills and competencies. This approach should foster the development of the students' own values: responsibility, organizational competence, self-discipline and higher intellectual skills cannot be developed from scratch by training on the job. These have to be developed at an early age in school.

A challenge to schools

There are positive views about this challenge: "One of the most challenging tasks currently facing schools is their ability, through the right mix of curriculum topics, teaching methods and community relations, to provide pupils with life skills ... for an IT environment. (These life skills) are by no means the only ones required, but they are of major importance. They include the ability to think clearly, and to express oneself clearly and concisely, both verbally and in writing.... Associated with clear thinking is the ability to structure a problem and its solution, a skill which applies equally well to programming, car maintenance and child care" [Bish84]. This challenge requires education to be re-thought and implies a substantially expanded use of technology and fully integrated applications of IT across the curriculum. It implies an effort which, according to the Office of Technology Assessment of the Congress of the USA, "will probably require new strategies and perhaps new authority" [OTA88]. This authority should be a legitimate educational authority, implementing long-term policies, capable of guiding practitioners, and of establishing points of reference [Baro89]. It should convince society of the need to invest much more in education, and also that a under skilled or unqualified work force is more costly to society, because dropouts will most likely have to receive welfare assistance at the expense of society [ISTE90].

Challenges to educational systems

To summarize the challenges, there are two critical issues for educational systems. The first follows from the fact that educational systems have "no control over the change forces that are fuelling the Information Age" [Mour91], but that they should respond to the evolution of society, an evolution which is strongly influenced by technology. The second issue is that educational systems have to offer students a socially useful, personally interesting and active way of life, based on the life skills formed while "living" in school. If the IT push as a global phenomenon forces an advance on these two issues, this would represent a major breakthrough in tuning educational systems to technological societies.

I. 4 Educational use of IT is changing

Introduction

Why, in what, and how to use computers in education are three questions educators permanently have struggled with since the introduction of computers in education in the 1960's. The answers to these questions have changed enormously in time. Although it is not the purpose of this paper to give an overview of the history of computers in education nor to review issues which have been discussed in literature, we will try to summarize the general trends whose evolution reflects the dynamic character of applications of IT in education. Such a summary is deemed helpful in understanding the present and in preparing for the future. Jacques Hebenstreit in his paper "Computers in Education - The Next Ten Years" [Hebe92] has much to offer in this respect.

The summary might be based on the "tutor, tool, tutee"-framework proposed by Taylor [Tayl80]. In this framework three, not necessarily mutually exclusive, ways of "using computing" in education find a place:

- the tutor mode, in which drill-and-practice programs, tutorials, simulations and educational games are used,
- the tool mode, in which information processing and retrieval tools (word processors, databases, spreadsheets) and application programmes are used,
- the tutee mode, in which micro worlds are constructed and explored, and in which programming plays a role.

However, to survey developments in each of these three modes of computer use would be outside the scope of this paper. In line with Alfred Bork's suggestion that the history of technology in education cannot be written linearly - it has to be "written" hyper textual -, we will try to summarize only the most basic points in which the changing use of IT in education is reflected.

Computer Assisted Instruction (CAI)

From the very beginning computers were used to provide instruction, drill and practice in many curriculum areas. Much was expected from the programmed "stimulation, answer, feed-back" cycle, to which students were systematically exposed sitting in front of a computer terminal. Early computer-assisted instruction (CAI) programs ran on time-sharing mainframe computer systems, centrally operated in remote locations. Some big and costly projects produced extensive suites of CAI programs. The advent of the microcomputer improved availability, variety, presentation and interactivity of CAI programs, but many of the programs produced are of little interest because they are just computerized workbooks. Many research projects have studied the effects of CAI and their results show a tendency find these favourable. However the methodological foundations of these studies have been frequently criticized. As the US Office of Technology Assessment states [OTA88]: "The main problem with the results of this 30-year body of research is that it provides no insight into how CAI produced those learning outcomes". From an educational point of view the main criticism on CAI drill-and-practice and tutorial methods is, that they embody the paradigm of a pedagogy aimed at using "the computer to push facts into the students" [Lick84] and disregard more creative uses of computers. For a critical review of uses of computers in education see Michael Streibel [Stre86]. Nevertheless it should be noted that many teachers deem CAI programs to be effective in supplementary or remedial mode and that find students benefiting from their use in combination with normal classroom activities. Also teachers who are judged on how well their students do on standardized tests, may take advantage of computer-assisted instruction [Gore89].

The role of programming

Computer programming - or a rough approximation of it - has had a clear presence in educational computing since the beginning of the micro-computer era. The focus of attention in schools at that time was mainly on hardware and on programming, usually with the microcomputer's native language (BASIC). The absence of high level programming environments appropriate for programming applications of information processing resulted in a wide spread custom to teach students some very limited computer programming, thus allowing only a very narrow view on the programming of computers and their operational power.

To support teaching of programming and to develop programs for computer assisted learning, the educational sector took the initiative to propose languages such as LSE and COMAL. These languages tried to gain acceptance by maintaining the virtues which made BASIC very popular, but also featured a form of modularity and of structuring needed for the teaching of programming. These kind of languages never had a widespread audience, except maybe in national context. In particular the French language LSE had the merit of proposing a nation-wide standardized programming language to foster the realization and exchange of educational applications, but also to cope with the special requirements of the French language and of the French educational system. Programming languages like Pascal, which were initially, in the early 1980's, not available on micro-computers, offered not a realistic alternative because their teaching required in-depth teacher training and they also displayed "editing, compiling, linking"-complexities. Nowadays these powerful languages are embedded in much better operating environments, thus creating programming environments which may stimulate their educational use.

Computer literacy and computer awareness

When, at least in some countries, micro-computers became widespread in schools, the pre-occupation with computer literacy and computer awareness began. These terms have never had a universally agreed definition, but here they are used to denote a perception of what (micro-)computers can do, know-how on software use and use of application tools, and awareness of some cultural and social issues related with IT. Computer literacy was found in the form of courses, which were generally short courses and lacked formal student evaluation. Most of the time some programming activity was included, which was assumed "to remove the mystery of those machines" [Mark91]. In general this lead, in the early 1980's, to a reduction of computer literacy to, again, BASIC programming.

Computer programming in general secondary education, both as a specific subject and as a topic in computer literacy, went in decline with the advent of more powerful machines and personal software tools. These machines and tools were not built to specifically satisfy the aims and needs of education, but were based on emerging industry standards. Marker and Ehman [Mark91], state that "today attention is on what the machines can do to help us with daily tasks, rather than on the inner workings of computers themselves". This emphasis on the tool aspect marks a shift in point of view and is part of a climate of natural acceptation of IT: "Increasingly, computer technology is taken for granted by teachers and students alike, because it permeates the world around them". From an educational perspective, the increased use of general purpose industry software implied emphasis on the information handling and productivity aspects of the student's work. The variety and sophistication of application programs (word processors, spreadsheets, databases, graphical and statistical programs, hardware and software interfaces to laboratory instruments, spelling checkers and thesauruses, desk-top publishing programs, etc.) is ever expanding and places great demands on IT-committed teachers. But they also offer real rewards in that they "make the computer a partner of the student" [Lick84] and also facilitate purposeful and meaningful uses of IT by the student, if properly coached.

However, the use of software tools in education is actually often restricted to the use of word processing tools. And "most student word processing time is spent learning how to use the software rather than using it as a matter of course to draft and revise papers and essays" [Beck91]. Although this experimental evidence seems discouraging, the same author expresses that the increasing proportion of computer time which is spent on word processing constitutes "a hint that computers will begin to take on new functions as general intellectual and information resource tools".

During the 1980's, the big technical advancements in and the economical significance of informatics resulted in social pressure on education to use computers, which pressure in many cases produced computer literacy type approaches. Cummins and Sayers say that "during an epoch it was thought that computer literacy should be a major goal of education because it is an essential prerequisite for a decent job in the future" [Cumm90]. The present stagnation of the informatics industry and the corresponding decline in available informatics jobs, might result in less societal pressure and also in lower funding. But less societal pressure or not, education must make clear that students will take much advantage from educational use of Information Technology to develop higher order skills. But also modern IT offers working tools to the student, even though these tools will usually not have been developed to be used in the learning process.

More and more curricula are designed with the aim to integrate IT into school subjects. This implies that computer literacy is becoming less a subject in itself and more a practical understanding capabilities and limitations of computers. Students, while using computers in their learning, gain experience with computer systems, with the processes these can support, with the peculiarities of human/computer interaction, and also learn to appreciate the computer as an intellectual tool, which helps in solving problems, in formalizing ideas and in investigations.

Micro-worlds, tools to think with

In parallel to the developments described so far, and somewhat independent of it, another category of educational IT use emerged based on the concept of "actor language". Languages, such as Logo and Smalltalk, were created aiming support the learning and experimenting of students at different levels of development. Logo specifically aims at creating an environment in which the student will gain personal experiences which will allow him or her to form new concepts, and to develop intuition and high-level cognitive and thinking skills. In practice the fact that the student should be free to program the computer as wished, sometimes led to a situation in which the student was left alone by the teacher and unable to progress. In many cases the inherent problem-solving characteristics of Logo were neglected while the task of coding and debugging got under way [Ewar89]: "Logo has been treated just as another programming language to be taught, the emphasis being put more in the commands and structures of the language than in the heuristic and exploratory environments that it allows to create".

Logo has had a big influence in educational computing and many teachers believe that Logo-based activities have powerful and spontaneous effects through the explorations it permits. However, there is experimental evidence that mere "opportunity" is not enough and that teachers have to play a role in the structuring and evaluation of Logo-experiences [Croo91].

Conclusion

At the moment, IT in education has taken quite another form than conceived in 1960's and even in the computer literacy trend in the early 1980's. In the use of IT in education there is a growing emphasis on student activities within the curriculum. Emerging technologies such as digital video, telecommunication networks and optical mass storage, will allow this emphasis to be strengthened. This development is at present the focus of much interest and research.

I. 5 International recommendations on IT and education

Introduction

In the early days computer scientists were experimenting with divers uses of state of the art computing technology in education. These individual pioneers played a leading role, but soon educational organizations themselves, and later regional and national governments came into play. Social and economic change, brought about by the technological developments, have forced educational authorities to specify their position and define policies in the field of Information Technology with regard to compulsory education. Many regional and national plans have been set up since the beginning of the 80's, aimed both at the introduction of informatics as a subject in itself and the use of computers in the curriculum. These plans encompassed organizational procedures, as well as schemes for funding computing equipment, software development and teacher training. IFIP's Working Group 3.1 "Informatics Education in Secondary Schools", Guidelines for Good Practice [Tayl91] provides numerous references to such plans. Accounts of specific national and regional policies can be found in many other documents, such as proceedings of IFIP congresses - all of these are referenced in [Tayl91] - or in the annotated bibliography provided by Baron [Baro89]. In this paper we will restrict ourselves to the position and recommendations of international bodies such as the Organisation for Economic Co-operation and Development (OECD), the European Community (EC) and UNESCO.

Recommendations of OECD

The OECD, an organization promoting the economic well-being of its member states, is aware of the high dependence of highly industrialized countries on technology and of the high technological competence, based on a high level of educational achievement, which is required of a significant proportion of the population. The OECD states that this "human capital" is a substantial component of the economic and social wealth of nations. Consequently it has studied carefully the global implications of IT in economy and society, and also the specific relationships between IT and education.

The views and recommendations of OECD on new technologies and education can be summarized [OECD87] [OECD88], in the following statements:

- There is a strong need to implement policies "designed to help as many people as possible to play a positive role, in which they can perceive themselves and be perceived as making a useful contribution to economic and social life".
- Educational systems are to be perceived as agents of normative development. Most aspects of modern technology require a significant proportion of academic instruction, and "technological change cannot be realised without the concomitant, even anticipatory, changes in the education and training system, to meet the requirement for a more highly skilled and educated workforce".
- To adequately prepare secondary education students for the new and changing working environments, "educational methods and pedagogy should be further developed to foster initiative, creativity, and responsibility".

Recommendations of the European Community

Based on the perspective of the European Economic Community that education and Information Technology play an increasingly important role in the general development of the Community, the European Commission (EC) formulated it as a necessity to use new technology throughout compulsory education and initial training, as much in the context of the curriculum as in the focuses and methodologies of apprenticeship [COM89]. The EC also stated that "to develop a balanced focus it is essential to introduce the new technology into the whole of the school curriculum and not limit it to sciences and mathematics." The objective is to introduce new technology into all stages of the education and training process, starting with general education which forms the basis of the development of human resources. It is necessary to emphasize the importance of this idea, which suggests that Information Technology should be known and used by as many people as possible so that no limited elite will dominate technological change. In particular, the European Commission puts special emphasis on students of both sexes acquiring IT skills and competencies .

These political directives of the EC for general education were materialized in a programme, launched in 1983, relating to the introduction of Information Technology into education [ECOJ83], and are completed by actions which extend to other formative fields. Programmes such as COMETT, intended to improve collaboration between universities and industry, and the EUROTECNET programme, which offers workers new opportunities for training and retraining and qualifies them to deal with constant technological change, are all addressed to the same global goal.

In conclusion the EEC supports development of human resources at all educational levels with special emphasis on Information Technology, aiming at the development of the human capital of the Community. This policy on human resource development should be a cohesive factor between economic and social policies which lead to the free circulation of people, capital, goods and services within a geographic space equipped with a common technological substratum.

Recommendations of UNESCO

The interest of UNESCO in informatics and its implications can be traced back to its own origin. Since then UNESCO has constantly taken action to promote the awareness of the political, economical and social roles of informatics in the national bodies concerned. It has also promoted regional programmes on IT which have been developed by its regional bureaux for science and technology. UNESCO's initiative in founding IFIP and the founding of the International Computing Centre (ICC) in 1960, later transformed into the International Bureau for Informatics (IBI), are living proof of UNESCO's commitment [UNES82]. These organizations have approached informatics not in a purely technical, but in a global way. They have advised on or carried out many national and international actions and have organized many specialized meetings, promoting international co-operation and the human dimension in technology. UNESCO has also published guidelines and recommendations for better teaching of informatics [UNES85]. UNESCO's education journals, such as "Prospects, quarterly review of education", have already for a long time included papers concerning IT in education.

UNESCO's sponsored congress "Education et informatique: vers une coopération internationale renforcé" (Paris, 1989), represented a major event in international dialogue on computers and education. The more than 500 participants of that congress, representing 93 countries and 29 international organizations, issued a statement [UNES89a] [UNES89b] which, although not an official UNESCO declaration, was an authoritative international declaration on the need to integrate IT in educational systems. Many of the statements in this declaration are well in line with those already quoted from EEC and OECD. Here we mention some other aspects which should particularly stressed.

The declaration urges:

- to reinforce international co-operation in order to foster innovation, experimentation and research with respect to the pedagogical applications of Information Technology,
- to use this international co-operation to soften inequalities between countries with respect to IT in education, while helping to preserve national identities, cultures and languages,
- to recognize the multiplicity of roles of IT, not only as a pedagogical tool, but also embodying a cultural change and a new approach to teaching and learning.

Finally, UNESCO sponsored a European seminar in Moscow in 1991 to share information and experience, and to develop co-operation between Eastern and Western European countries with respect to Information Technology in education [UNES91].

Conclusion

From what has been mentioned it is evident that these major international organizations are concerned about the multi-faceted relationships between IT, education and society. The overall perspective is much wider than the first "technical visions" of individuals and teaching institutions pioneering with the use of computers in education.

It is furthermore worth to point out that there is a trend for governments, at least in the industrialized countries, to limit the scope of their activities. This trend can have a beneficial effect on school systems and individual schools if openness to society, autonomy and self-help is fostered. But still government, local authority and society may put more demands on the school system to produce the "human capital" needed. A report of the World Bank on world development states that governments will not be able retreat from at least five basic areas: political stability, human resources, stable macro-economy, competitive micro-economy and openness of the economy to world trade. This implies that, next to maintenance of the stability of society and of international relations, human resource development will be a major focus of government activity. Information technology in education will probably be more and more in the centre of public attention and expectations.

I.6 IT in education: from introduction to integration

Introduction

In spite of years of buzzling activity, a large number of people involved and the importance attributed Information Technology in education, with a few exceptions, has been or is in a experimental, exploratory or introductory phase. Many of the institutional plans for IT in education are defined in terms of the words "introductory" or "experimental" and aim at the initiation of the students in IT as a subject and the use of IT in some curriculum areas. There is growing understanding that these experimental plans do not go far enough to fully exploit the potential of IT for improvement of secondary education. Earlier we mentioned the changing perception of the educational use of IT. This shows that IT is not just a school topic in itself and also not just a complementary methodology. Because of its close relationship with the student's basic skills, values and competencies it requires a more committed, systematic and extensive approach than usually found in these introductory plans. An approach going further than introduction could be labelled "integration of IT in education". However, the unresolved mismatch between the new technologies and the traditional curriculum make it difficult to give an unified meaning to this concept. In fact, [Whit89] states that "the current word integration ... offers anything but a poor compromise for instruction".

What does "integration" mean?

Proposals for the meaning of integration have been made. According to Dudley and Dudley [Dudl90], integration means using the computer as a tool to teach material in a discipline, and also using the computer in existing curricula to promote problem-solving and higher-level thinking skills. The power of the computer is applied to facilitate decision-making, to amplify on concepts, to support synthesizing. In short, integration is defined as "the process of applying the power and ability of the computer to learning in every subject area". With integration goes a clear perception that IT is not identical to computer literacy or computer awareness. And also the acceptance by the community in which the school is rooted (teachers, students, parents and schools' administrators), that Information Technology is part of everyday life in and outside school.

Thus integration of IT in secondary education implies a move towards a whole new school reality by means of co-ordinated development. In this development action is required with respect to:

- aims of general secondary education,
- meeting new demands of society on students skills,
- reform of curricula,
- training of teachers in new skills,
- internal school organization,
- hardware provision and maintenance,
- stabilization of funding policies,
- support by technical staff,
- equity of access for all students,
- software development and provision,
- development and provision of complementary materials,
- copyright policies for software.

Policy for integration

The interplay of the actions on those issues requires a global policy. This policy should be based on basic consensus between teachers, managers and politicians with regard to criteria, people, and organization. Some statements can be made about these three policy elements.

(1) General criteria:

- IT is not an end in itself, but a powerful tool for changing education by extending teaching and learning processes,
- there is no single "best use" of Information Technology in schools to improve learning,
- much more research is needed in human learning and cognition.

(2) People:

- human factors are the most critical in accomplishing the expected goals,
- students have a right to be able to develop needed values, abilities, knowledge and skills,
- professionalism and capabilities of the teacher must not be underestimated,
- resistance to change can be counterbalanced by participation and co-responsibility.

(3) Organisation:

- integrating IT in the school life is a difficult task which requires time, commitment and rewards,

- management of IT requires much attention because it "depends on scientific knowledge and instruments, and assumes an organizational fabric which is itself complex to operate" [OECD88],
- funding and support should be provided on a stable basis.

All these points should be taken into account in any policy aiming at integrating IT in secondary education. In the second part of this paper we will analyse the main factors influencing the integration of Information Technology in teaching, learning and school life.

II Main Issues and Perspectives

In part II of this paper the following factors influencing integration of Information Technology into education will be considered:

- Secondary school curriculum,
- Teachers and teaching,
- Students and learning,
- School policies and school organization,
- Computer hardware,
- Software for education,
- Secondary education and telecommunication,
- Funding and cost-effectiveness,
- Equity issues.

II.1 Secondary school curriculum

A framework for innovation

There is experimental evidence for the needs of society and the individual with respect to Information Technology, as outlined in Part I of this paper. A survey carried out by Plomp [Plom91] shows that these needs in many countries are the motivation for the introduction of computers in secondary education. However, there is no direct link between global educational aims (such as improving student achievement, having students acquire skills for the future, promoting individualized and co-operative learning), following from these needs, and the concrete objectives of education (such as: curricula, educational targets, teaching methodologies and organization of learning activities).

This lack of a clear and worked out relationship between general aims of IT in education and secondary school curricula is one of the main problems which prohibit successful integration of IT in secondary education, well beyond innovators' initiatives. It is imperative that curricula include precise frameworks for integrating IT, to avoid pitfalls like:

- the innovation is neither profitable to a majority of students, nor lasting, because teachers do not know what is expected of them,
- without proper educational objectives teacher training becomes tool-oriented, and is made obsolete,
- the lack of a rationale leading to continued funding and support.

Curricula to be defined by regional or national bodies

When an innovative curriculum is not officially established, teachers or even whole schools which want to implement IT, come into conflict with the actual curriculum. The traditional curriculum is in general a compromise between academic tradition and conflicting interests of very different kind and origin. This compromise is defended not only by its supporters, but also by specific mechanisms in the educational system. This situation of conflict is difficult to overcome at school level.

Therefore the definition of a new, IT integrating school curriculum, which is to be accepted by teachers, to be compatible with the practical capabilities and resources of schools, and to be designed for straight forward implementation, is a major task which has to be addressed at the level of the bodies governing formal educational systems.

Some countries, such as Great-Britain, have recently defined new national curricula, integrating IT in a cross-curricular way. The discussions leading to it have shown "virtually universal assent" [Brow90], so "the educational case for the use of IT across the curriculum looks to be won".

How to implement an innovative curriculum?

There was much educational experience on IT available in Great-Britain prior to the publication of the Statutory Orders which established the national curriculum. In spite of this high level of experience and widespread use of computers in secondary schools, the "practical implementation of a renovated curriculum is not easy and requires guidelines and examples of good practice that could enlighten the way to proceed" [SED87]. To contribute to this implementation Her Majesty's Inspectorate published some particularly worthwhile documents which stimulated discussion about the curriculum as a whole and supported schools in devising strategies for coherent and effective use of IT [DES89]. Along the same lines the Department of Education in Northern-Ireland [DENI89] produced five cross-curricular strands of expected learning outcomes for the student: communication (of ideas and information), information handling (including criteria on accuracy and validity of information), modelling (including simulation), measurement and control (interaction with the physical environment), and evaluating the impact of Information Technology (for society and the individual). This document explicitly states that IT should be applied in the basic cross-curricular processes which require information processing:

- designing, creating and composing,
- presenting and communicating,
- calculating,
- measuring, recording and controlling,
- selecting, testing and evaluating.

These processes are central to almost any educational activity which is carried out by the student and each one of these may be supported and enhanced by a proper use of more general IT tools and methods. Software tailored specifically to suit certain subjects may also be very useful to help teachers of specific subjects (language, mathematics, visual arts and music, social and experimental sciences and others) to customize these general processes to concrete objectives, content and levels. There have been designed exemplary curriculum outlines for this purpose [DENI89] [CCW90] [Hunt90]. Fothergil [Foth88] gives a thorough and comprehensive account of the implications of the new technology for the school curriculum, and [OECD87] focuses on the relationship between Information Technology and basic learning (reading, writing, science and mathematics). School curricula like the ones commented on so far seem to be the most promising way of integrating IT in secondary education, because these offer every student opportunities to get involved with Information Technology in almost any subject area.

Infrastructure needed

Coming back to UK's paradigmatic case, it can be added that the level of integration demanded by the statutory orders on Information Technology within the national curriculum is high, and "will not be achieved without improved access to the hardware and software which are fundamental to teacher's needs to develop such a curriculum in schools" [Wild91]. The required accessibility of hardware and software for an increased use of and integration of computers, needs an explicit management policy at school level and also sufficient support, training and time. According to the Curriculum Council for Wales [CCW90], two important general comments should be made on the process of implementation:

- The planning, delivery and monitoring of IT across the curriculum needs to be co-ordinated very carefully, and it is an especially complex task in secondary schools,
- An IT framework for each key stage and a school policy for IT are both central to the ongoing development of IT in the curriculum.

It is worth comparing the cross-curricular and integrated approaches mentioned here with those in the mid 80's. A document from 1986 [OECD86] explained that "The impact of technology at the secondary level is most evident in the addition of new courses, less evident in the modification of existing courses, and minimally evident in terms of interdisciplinary involvement". The same document reported a United States study which indicated that in large school districts the focus was on programming skills or computer theory and that "the only modification of existing courses has occurred in the areas of mathematics, science, and vocational education. Other subject areas are relatively untouched by the new information technologies".

At the moment we see the focus in the secondary education curriculum shifting and under the influence of needs and perceptions as outlined in Part 1 the school's curriculum is permeated with IT-based innovation. This development is in parallel with developments in technical resources and in training of teaching and management personnel which is building up a collective expertise.

The practical implementation of new IT-integrating curricula should take into account the variety and irregularity of IT knowledge and experience which the students have when entering secondary school. There will be students who are not at all familiar with computers. Others will have experience gained through computer awareness courses. There will also be students who have for example Logo experience or who even master a few IT tools. To create a common background there has to be identified what the students have learnt in primary schools, and appropriate action has to be taken to ensure an adequate individual development of the students in secondary school. In future national curricula must ensure coherent student experiences in primary schools facilitating easy transition from primary to secondary school.

II.2 Teachers and teaching

II.2.1 Teacher development

Introduction

The introduction of computers in education, and even more their systematic integration into teaching and learning, are innovative activities which need serious consideration by planners on at least two main points:

- personnel which will be involved in implementing the innovation,
- the organizational context in which the innovation will be developed.

In this section we consider the first point, limiting our focus to teacher development. Students, administrators and other personnel are obviously part of the innovation process, but their development will be considered later.

Information technology-based innovation asks for changes in teacher skills, knowledge and attitudes. These will only be lasting changes if supported by permanent teacher development and by an appropriate organizational context. Specific issues in teacher development are:

- teacher training, and
- teacher support, aimed at overcoming teacher concerns.

Teaching skills and teacher motivation are also important aspects and will be treated separately in following sections.

II.2.1.1 Teacher training

Usually there are specific plans or programmes at national, local or even school level which address the issue of teacher training in educational Information Technology. This in recognition of the fact that IT-based innovation without quality teacher training and development would be markedly unsuccessful. The development of human resources in education should however not be the object of punctuated, short term actions, but must be dealt with as part of teacher development over the mid term. Training plans should be flexible and have a modular structure and training should rely heavily on well-developed learning resources. Furthermore, the use of the same type of software and equipment as available in schools will contribute to bridge the gap between training and teaching. In-service training should be within easy reach of every teacher both in time span - for personal planning - and in geographical distribution.

Teacher training, both pre-service and in-service, is a very broad field for which many specific plans have been made and much research has been done (see for instance: [Lovi88], [Boll88], [OTA88], [TTEC91]). Here we will briefly consider some of main issues and recommend criteria which should be used when taking action. Many of the common characteristics of retraining programmes for teachers in the discipline of informatics which are quoted in IFIP's WG 3.1 "Informatics Education in Secondary Schools", Guidelines for Good Practice [Tayl91], may also be usefully applied to the retraining of teachers in the use of IT in their teaching.

In-service teacher training programmes should take into account that IT confronts teachers with a learning situation of their own: the teacher as a learner. This is a difficulty, but also an opportunity, in teacher training. There are many similarities between the learning of a student and the learning of a teacher, both in pre-service and in-service education; teacher and student often have analogous learning difficulties. These may, among others, be caused by different starting levels in knowledge or different personal expectations. Learning difficulties also arise from an excess in teaching of theory: the theory taught is often not enough brought into practise by the students and sometimes even actually not used in the teaching itself. In training programmes there should be enough encouragement and opportunity to apply the acquired IT-related abilities in curriculum areas. Also the content and the style of teaching often depend too much on available hardware and software: on the one hand the teaching may be based on obsolete and unattractive resources, on the other hand it may depend on the latest advances, or even gadgets, of technology.

The reasons mentioned, together with others such as the irregular provision and uneven quality of the in-service teacher training itself, may explain that long-term effects of in-service teacher training in IT fall behind expectations. It should, however, be taken into account that the general problems of a broad in-service teacher training have not been solved yet.

Criteria for teacher training

On the basis of the ideas mentioned and of research results from a wide variety of sources, the main criteria for successful teacher training in the educational integration of Information Technology may be summarized as follows:

- Highest priority should be given to the discussion of the relationships between the use of IT, primary curricular goals, learning processes and student activity.
- Explicit attention should be given to the organizational factors and didactic strategies, in relation to the teacher's ability to deploy specific teaching skills, which are most suited for the integration of Information Technology into a variety of disciplines and classroom settings.
- Teachers should be provided with models, examples, and detailed comments on how to use a variety of computer applications.
- Training time on software tools should preferably be spent on standard application programs and on well-constructed, properly documented and easy-to-use educational software.
- Much of the technical jargon and hardware complexities should be avoided which put the training out of educational focus and discourage teachers.
- Fundamental Information Technology concepts and information skills should clearly be distinguished from contextual and particular techniques.
- The training curriculum should be resource-based (hardware, software, documentation, guides, worksheets and other), technologically not static, and pedagogically flexible, allowing team-work and school-based practice.

These criteria may help to achieve a pedagogically sound integration of Information Technology within the curriculum. As Norman points out, there is empirical evidence that "the most pressing need for teachers inexperienced in these new technologies is to acquire an understanding of their procedures and the corresponding 'mental set' which allows uninhibited and creative use of them" [Norm87]. Enough training time in a convenient time span is also a prerequisite. IT was not included in pre-service teacher education when most actual teachers were trained and the majority has a very limited experience of Information Technology.

Every teacher should have at least a minimum level of IT-related training, therefore availability of this training is an important point to address. Continuous development of large numbers of secondary education teachers, with a wide range of interests and many different levels of experience in Information Technology, cannot possibly be done in the traditional courses; it may be necessary to focus on open and distance learning systems supported by IT itself. There already are approaches to teacher in-service training based on telecommunication, in which teachers take a greater responsibility for their own learning. These approaches show a large variety in selection of content, methods, freedom of time and place, and forms of evaluation [Gray89] [Ruiz92] [Simo92]. In-service training by resource-based self study and small group study with distance learning methods requires appropriate learning and resource materials and a well defined and structured support. Instructional materials may be paper-based, audio-visual, or Computer-Assisted Learning systems. Distance resource materials and support may be provided through telecommunication by tele-conferencing, E-mail and information retrieval facilities.

Pre-service teacher training

A final consideration on the teacher training aspects is that the long-term efficiency of integration of IT in education urges to also put major emphasis on pre-service teacher training. Systematic education of all future teachers will constitute the best way to cope with student needs and the evolution of IT. In this line of thinking the totality of pre-service students and an affordable part of the in-service teachers should be educated to be able to integrate IT into the curriculum, taking into account teaching skills and organizational factors. The experimental experience and the present knowledge about education and in-service training, could advantageously be transferred and re-invested in pre-service education.

II.2.1.2 Teacher support and teacher concerns

Teacher support

Teacher support is another key-concept in teacher development which must be distinguished from operative support at individual level, that is, specific actions to overcome equipment-related operating problems or software operation procedures. It must also be distinguished from technical support at school level, which is aimed at the continued operation of IT hardware and software resources, the actualization of computer programs and facilities, and the security of information. Technical support is usually formalized at the school organization level or at the local educational authority level.

By teacher support we mean a collective set of measures and actions: working groups, topic-oriented projects, pedagogical orientations, presentations of new materials and methodologies, evaluation and assessment activities and other initiatives, which are based on already existing experience from formal pre-service or in-service training. This support, provided with adequate pace, continuity, participation and leadership, may be the most basic asset for innovation, stimulating and helping the teacher to develop his role as the main agent of innovation.

Teacher support is needed because just the availability of software and having trained with it "is not nearly a sufficient condition for frequent and integral use, particularly when software requires a new approach to teaching and learning subject-matter and is not just an analogical transformation of paper-and-pencil activities" [Beck91]. Support may also help in overcoming many practical problems which are often overlooked in formal training and which hinder the innovation process. Peer-to-peer support, support from advisory or experienced teachers in informal and friendly sessions increase the confidence of teachers and might be the most effective teacher training mode. School policy should make provisions for teacher support and local or district educational authorities should be actively engaged in this support.

Teacher concerns

Teacher training, and more specifically teacher support, may help to eliminate or at least lessen anxiety about IT. The Office of Technology Assessment [OTA88] indicates that the main concerns of teachers are: fear for uncertainty, changes in the relationship teacher and student, and concerns over the accountability of progress by the students. Underlying these concerns there is the need to learn new strategies on how to effectively turn information into knowledge under the opportunities and pressures of technology [LaMo90]. All these factors imply a re-examination of the role of the teacher which is not easily done by practising professionals; this may be easier in future after the integration of Information Technology in compulsory education and in pre-service teacher education.

II.2.2 Teaching skills

Information technology directly influences the basic aspects of teacher behaviour and performance. Every teacher has technical teaching skills which, subconsciously or not, produce specific behaviour in managing the classroom, in attaining curriculum goals and in stimulating desired learning by students. In our view the implications of IT use for teaching skills have not been a subject of study and research, and have certainly not been systematically addressed in in-service teacher training. Magda Bruin [Brui87] states that "the didactics of computer usage is a virtually unexplored area and the general inability to make proper use of the available software in education is a consequence of this fact". This fact may help to explain why it is not enough to introduce teachers to Information Technology when the aim is to have them use IT in the classroom.

In the analysis of this issue it may be helpful to take the view of Turney and colleagues [Turn73] who identified seven categories of teaching skills:

- motivational skills,
- presentation and communication skills,
- questioning skills,
- skills for small group work and individual instruction,
- skills for developing student thinking,
- evaluation skills,
- skills for classroom management and classroom discipline.

Motivational skills

These skills aim to enhance student involvement with her/his own learning and with classroom activities. Motivation implies selection of an appropriate stimulus level, support of student feelings, reinforcement of behaviour, identification and fulfilment of student needs. Teachers may plan the use of IT as a motivational factor in different ways. A teacher may present access to a computer as a rewarding factor in itself; growing availability of computers and student familiarity with computers makes this a less promising approach. An alternative may be access to challenging programs, such as games and simulations; this may, however, be easily labelled as excitement instead of motivation.

Teachers should investigate whether the real motivation of students is maybe caused by a use of IT which gives them a personal sense of control over the tasks they are doing and which makes them appreciate freedom, interactive work, an easy user interface and a computer suited to their own needs and interests. Computers are, however, no panacea for sustaining student motivation; to keep the IT-motivation alive will probably require teacher skills for proposing to the students sensible and productive uses of the computer.

Presentation and communication skills

These teaching skills help to "dramatize" and include skills in reading and explaining with adequate pace and rhythm, in moving around the classroom, in voice modulation and expressive body movement and should take account of the physical condition of the classroom, laboratory or lecture hall. These skills also imply mastering the support of a variety of materials and technological aids, ranging from blackboard and chalk to computers and video displays. The computer may be used as a presentation aid by the teacher, who has to co-ordinate her/his actions with computer input/output. It may also be used to reinforce a presentation to students working individually or in small groups.

Use of computers changes the classroom layout and student attention is often more focused on the computer than on the teacher. The absorbing nature of computer use may lead to a too central position, lessening the role of the teachers to an undesirable extent.

Questioning skills

In close connection with communication skills, questioning skills aim to stimulate feed-back from students which helps to focus the activities of both teacher and student, and to stimulate student initiative. The use of a single computer in the classroom as a presentation aid under teacher control does not change questioning techniques very much. But the situation is completely different when students are working with computers, alone or in small groups. In this case the teacher has to be able to cope very rapidly with a variety of situations, at least one per computer, and has to pose questions to the students helping to overcome the difficulties of the instructional process in which they are active.

Skills for small group work and individual instruction

One of the main functions of teachers is to organize individual and small group work, aimed at developing both independent and co-operative learning. The microcomputer is especially suited for individual work, both by hardware design (a single keyboard, small-sized screen, one user, one task) and by program design (almost always designed on the assumption that it will service a single user). Teachers may take advantage of this orientation to individual work and assign tasks to individual students which are especially suited to their abilities and their achievements in the learning process.

We believe that in a small group of students working with a computer the level of interaction between the group members is raised significantly and that each student attains a higher level of understanding than when working individually. Teachers should be aware that students usually assign themselves specific functions according to peer relationships, academic achievements, keyboarding skills, and other criteria. To avoid undesirable learning effects teachers should ensure a balanced distribution of learning tasks over the group. More information may be found in an issue of Computers and Education [C&E91] dealing with the interaction between students working with a computer in small groups.

Use of IT in a small group and for individual instruction engages teachers in a counselling and encouraging role; students tend to see them more as counsellors than as instructors. It should also be mentioned that students tend to produce more written materials when using IT, teachers therefore have to keep up with an increase in student output.

Skills for developing student thinking

These skills are aimed at helping the development of concepts by the student, at fostering and guiding discovery and problem-solving processes, at using simulation and gaming to stimulate thought, and at encouraging students to evaluate and think critically. When using IT, the tasks aimed at the development of student thinking are to some extent shared between the teacher and the computer. Some tasks might even be completely transferred to the machine. The teacher has to recognize which tasks belong to the student-computer partnership and has accordingly to adopt her/his own strategy. This may lead teachers and students to think that teacher strategy and activity are subsidiary to the strategies of the software. However the teacher plays her/his own role and will help to explain facts or rules assumed already known by the software, or will give help when the student needs it. More discussion on teaching strategies and thinking skills may be found in [Ryba90].

Evaluation skills

These play a role when a teacher recognizes and assesses student progress, diagnoses learning difficulties and provides remedial techniques. These skills may, however, also be used to foster self-evaluation by the student. Computers are used to administer tests, to keep track of student activity and even to assign a qualification. Evaluation is, however, a central task for teachers and they therefore have to constructively handle the evaluation information the computer can provide.

In a classroom situation involving activity with computers, the teacher has to make a "real time" assessment on which student difficulties are conceptual (that is, relative to the subject in itself) and which are functional (that is, related to the software or hardware tools). This is a new evaluative skill which did not exist before computers were used in the classroom.

Skills for classroom management and classroom discipline

These skills aim at recognizing student behaviour, supervising class group work, encouraging task-oriented behaviour, and coping with multiple issues. There are indications that an adequate use of computers reduces discipline problems in the classroom: students are more concentrated on their own work and more problematic students are more easily engaged in a meaningful activity. There is evidence that in the case of difficult students the success of the computer is a key factor in the reduction of discipline problems.

There is also experimental evidence that teachers tend to think that the use of computers diminishes their control over their class, even in the case where they have planned specific activities to control the classroom. The examples given by Martin [Mart91] are eloquent enough in this respect.

Conclusion

The teaching skills mentioned so far emphasize the behavioural aspects of teaching. These have been critiqued because this emphasis would diminish intellectual and creative aspects of teaching [Dunk88]. Dunkin states that the definition of technical skills of teaching "has been broadened in more recent years to include diagnostic, analytic, and hypothesizing skills rather than the more strictly observable behavioural skills". He argues that IT use in the classroom requires at least two additional teaching skills:

- skills to decide on the suitability of the great variety of information and software resources,
- skills to properly cope with the differences in student learning behaviour which are sharpened by the use of IT.

The first type of skills is mostly to be used in small group and individual instruction. Information technology requires teachers to have skills for providing students with appropriate information resources and software material, for fostering self-access of students to resources and for producing ready-for-use materials (such as a guide to a piece of software or a worksheet for a program).

The second type of skills has to do with the fact that IT introduces further differences between students. These differences have to do with skills for functioning in a technological environment, with the social diversity which arises from having or not having a computer at home, and with use of a computer as a personal instrument for which the teacher can assign specific tasks. Although teachers always have had to cope with student differences in ability and interest, these differences now become more marked and deserve special attention.

Teachers should keep in mind that, while they are confronted with the many implications of IT for their teaching skills which deserve attention and time in teacher training and teacher support, still a large part of their teaching does not involve direct use of computers. IT is a resource among other resources and "Whilst teachers need to feel confident about using Information Technology, their general skills as teachers are of greater importance than high levels of technical 'know-how'" [CCW90].

II.2.3 Teacher motivation

Information technology increases the demands on teachers knowledge and skills. The same is true for many other employees and professionals. Teachers, however, often feel that no rewards are being offered to them as a compensation for coping with a situation that goes beyond their perceived duties. This fact directly affects the motivation of teachers to involve themselves in demanding innovation processes. In many countries the low salary level and diminishing of job rewards in the teaching profession - compared with other professions for which similar qualifications are required - hinder the reshaping of education in response to technological change. This is a structural problem with no easy solution, because, as the OECD [OECD88] states, "Selective increases, which might permit more effective competition for qualified personnel, are usually blocked by the institutional requirements of inter-subject equality in teaching pay structures."

Participation in innovation planning and assessment is another factor of teacher motivation to be considered. External or administrative pressures on schools to adopt computers may easily be met by a reactive attitude which could seriously hinder the attainment of the innovation objectives. Every successful use of computers in the classrooms has to be based on discussion and collaboration, the participation of teachers in the whole process of implementation. School policies on IT should take account of this.

II.3 Students and learning

II.3.1 Adult world influences

IT influences in the adult world

Students have to achieve learning goals of increasing mental complexity reflecting the adult world. In order to get a student centred perspective reflecting the reality of human behaviour in society we will analyze place and role of Information Technology first in the adult world and then in world of youth.

In the adult world, the Information Technology is used in three main areas:

- production,
- applied research, and
- theoretical research.

Production

Production, which includes business and professional use, increasingly depends on the integration of IT into the manufacturing process: from robotics found in the automobile manufacturing industry to the integrated sales and stock control systems of a large supermarket. Adults in these cases need skills to efficiently use and manipulate these tools, but need not reflect on the underlying structure and functions. It is expected that all jobs, even the most simple ones, will soon include IT activities of some sort.

Applied research

Applied research is driven by the need for better and cheaper production, which requires development of more and different IT devices. Large industries and companies have their own centres of applied research, including informatics departments. Competition between IT industries is encouraging applied research in the areas of user-friendly interfaces, expansion of memory size and capitalization on the speed of processing. The skills required for such innovative applied research are of a higher mental order and involve capabilities for creativity, analysis and abstraction.

Theoretical research

Theoretical research is not involved with direct responses to the needs of production or business; it anticipates on needs and provides conceptual frameworks. Such fundamental and long-term research is found in academic and large research institutions whose function is to devise and provide an environment supporting the scale and level of activity. An example of theoretical research is found in the work exploring neural networks in the human brain and parallel electronic networks in computing; another example is found in the area of virtual reality.

Adult world influences on the world of youth

The adult world is not only demanding new capabilities from students when they leave schools, but also providing schools with new realities, new problems, and new solutions. It is the evolution of the adult world which is leading the evolution of what is taught in schools, and not the other way around. Schools must be familiar with the changing use of IT in the adult world and incorporate this knowledge into the content of what they teach. Applied research supplies ways of thinking and working which have an influence on the nature of the disciplines, especially in the vocational and technical areas. For instance, design and technology syllabuses must now include use of computer graphics because of computer aided design (CAD) which is found in the adult world of industrial and commercial design, e.g. in architecture and engineering.

Information technology also impacts on more classical domains: general disciplines have been directly touched by developments. The time lag between the development of new knowledge in academic and industrial laboratories, using new IT techniques and methods, and the introduction of this knowledge into school subjects is getting shorter and shorter. For instance, in biology research results in genetics of less than 10 years ago are already part of the school discipline. It is of pedagogic value to present these new contents within the context of the developments in IT at the time of their discovery. This is partly the reason why it is necessary to introduce the use and value of new technologies.

But not only industrial, business and professional areas from the adult world influence the learning of students in schools. The academic world, working on theoretical research in classical disciplines and other domains which are not directly taught in secondary schools, also plays a relevant role in the introduction of IT in education. The more traditional academic disciplines of psychology and sociology have always played a part in the understanding of cognition and social behaviour of learners. Recently these disciplines used IT to broaden the debate within their own disciplines, but also to extend the understanding of learning. The confluence of informatics, linguistics, psychology, neural sciences, and artificial intelligence has already shown that it is very effective to have people working together from these different backgrounds, different approaches and different ways of thinking. With respect to education, much progress may be expected in the understanding of human brain processing, learning capacities and abilities, but also in understanding why some people have difficulties in achieving tasks where others succeed quickly. Experimental environments, expert systems for beginners as well as diagnostic tools, could be part of the future resources offered to learners and educators. But it might also be possible that students use professional expert systems. Once specific pedagogic interfaces have been created, expert systems, providing the thinking skills and logical intelligence/reasoning skills of experts, are tools which expose the learner to a high level of thinking and explanation.

II.3.2 Impact on the world of youth

Information Technology is not limited to school. It would be dangerous to assume that all children have the same level of contact with IT outside the school. It might be possible that young people compartmentalize and separate their experiences of IT inside and outside schools in the same way that they do not relate the work on co-ordinates in mathematics with that in geography. In this paper we acknowledge the potential influence of the outside world, but we only cover those areas which students need to explore at secondary school. Three areas of student learning with IT will be considered:

- use of IT tools and general IT skills,
- IT as a tool to support and extend learning integrated into different school disciplines,
- development of general mental skills, which IT can support and encourage (for instance: decision making, collaboration, development and testing of hypotheses).

Use of IT tools and general IT skills

The particular skill of operating a particular type of robot or bar code recognition device is part of vocational training in the adult world and these particular skills therefore should not be trained at school. What schools should provide is general knowledge of the existence, nature and role of such facilities. Students need an operational competency in IT to use packages such as word processors and spreadsheets. Students should learn the main characteristics of IT use rather than only how to use a particular package on a particular machine which happens to be the one in school. It is also important that these skills are not just taught in isolation in blocks of IT skills lessons, although for many schools this may be the only way to provide a level of competence for all students. Students need to exercise these skills during their normal work in the school or else they still will consider IT a special, rather than normal activity in the adult world. Laptops and notebooks will place the facility to use IT to support learning activities in the hands of the learner in the same way as they expect to use IT to support their work in the adult world. From this point of view the flexibility in resources is probably more important than their quantity.

IT as a tool to support and extend learning

IT interlocks with all disciplines in the adult world, in industries as well as in research laboratories. Integration of IT in schools should reflect this reality. Biology and mathematics, as well as geography or economics are developing new concepts and new methods because of the existence of Information Technology tools. Reflection of this reality in curricula and in teachers training may be the only chance to achieve IT integration in schools. Teachers will then be involved in their own field of interest and domain of competence, and students will want to develop useful skills in order to cope with these disciplines and their evolution. This integration is the responsibility of curriculum designers and teacher trainers, as much as of practising teachers. Limiting IT use to isolated CAL or word processing activities is most certainly a reason why so few teachers are now integrating IT into their normal teaching. They are dealing with other more important problems, such as heterogeneous classrooms, overcrowded classrooms, rates of abandon or failure.

Let us give some examples. The use of algorithmic models in economics provides a new experimental environment with which to explore the implications of different variable interactions. In geography use of real-time satellite images has facilitated a greater level of cross-curricular activity. Study of vegetation patterns draws the physicist into the discussion with respect to differential wave patterns, which determine the signal received by the satellite, and also the biologist with respect to the effect of temperature and moisture on the ground. Both of these provide an integrated explanation to support the subsequent geographical interpretation of the variation of vegetation in the landscape. Such an integrated approach to a subject has both stimulated cross-curricular co-operation and teaching, but has also opened up possibilities for a new definition of syllabuses.

Development of general mental skills

Problem solving skills are both particular to a discipline and at the same time have a general extension. For instance, problem solving in experimental sciences is not the same as in human sciences; it involves different concepts and goals. Nevertheless, from different problem solving methods some higher level and more general global methods may be abstracted. Too often it has been assumed that pupils using a computer for problem solving in a particular discipline automatically develop these general problem solving skills. But this is not the case: students have to be taught these more general skills and it is not obvious that all pupils will reach these higher levels of mental activity. It is, however, also not obvious that the teaching community has understood this fundamental problem.

How can computer use have a positive effect on general problem solving skills? Posing and testing of hypotheses, for instance, involve skills which form the basis of much human thinking. IT use in a variety of curriculum and other activities within school facilitates these activities, but also the search for and analysis of supportive data. The development of general mental skills through the integrated use of IT poses a particular challenge to teachers in secondary schools because so much of their work is confined within discipline boundaries. These general skills also include social skills, such as co-operation and collaboration. Much of the value of IT use, eventually including telecommunication facilities, is to be found in the group activity around the keyboard, or between distance keyboards. These group activities stimulate interaction, not just between the students and the software, but amongst the students themselves. This interaction takes place both at and away from the keyboard, stimulated by work on a common project. Group dynamics are an important aspect of learning. The environment for active learning which the use of IT facilitates, integrates well with the aim of developing these social skills amongst the students. This aim fits well with the demands of the adult world team work and other sophisticated forms of collaboration and co-operation. These skills, however, rarely appear in the definition of a subject syllabus.

II.3.3 Changing student behaviour

Introduction

The perceptions and needs felt by individuals, students, parents or teachers, are as significant for the role of IT in schools as the demands from the adult world of production, business and research.

It is obvious that students, more than teachers are now in the focus of education; students are more and more seen as pro-active actors rather than passive receivers within the educational system. This is illustrated by the fact that students now often pose demands on the content of personal projects.

Teachers exercise influence on the students, and not only when they are directing their classroom. They exercise influence by the way they use IT to support their work, e.g. to produce worksheets. But also others, like librarians, tutors, older students, in the student/school environment exercise influence. The role of the teacher is evolving into a new one: teachers form part of a larger education system which includes several other IT based information resources; they use less time for transferring knowledge and concentrate more on individual support and didactic approaches suited for those having difficulties in learning. This new role requires attention for specific aspects of human behaviour, such as co-operation and collaboration, values and attitudes.

Co-operation and collaboration

Most human endeavour in the adult world depends on individuals working in groups or teams. These teams function because the individuals are prepared for team work and know how to co-operate and collaborate on a range of tasks. These skills of patience, respect for different methods, capability for compromise achieve solutions which may be found along different routes, and not one set route. Schools increasingly encourage group work amongst pupils in order to experience and develop co-operative and collaborative skills. The complexity of many IT tasks provide an environment where these skills are essential. In particular the use of local and distance networks depends upon use of collaborative skills. Thus IT may supply both the environment which needs co-operative skills and the tools for developing such skills. Ironically the use of computers has also been seen to encourage individual isolation in some students; such tasks as programming are often perceived as an individual activity which may encourage those who are already disposed towards isolationist behaviour.

Simulation of human problem solving includes behaviour as an important variable. Different sets of values and attitudes, which are part of individual as well as group and society characteristics, are useful variables in a model of problem solving simulation. Role playing may enable students to explore reality themselves through technology. In modelling human behaviour the social and behavioural sciences have supplied both the world of education and the adult world with useful tools. For example, many industries now use IT models to simulate a crisis. Aim is not only to explore the most logical solution to a future crisis, but also to identify unexpected behavioural patterns which may emerge and have to be accommodated. In schools, a simulation of a planning application can involve students in exploring the conflicting attitude of a land-owner, government planning officer, conservation groups and local residents. Through the direct interaction with the model students perceive that these actors have different values and attitudes which need to be accommodated if a solution is to be satisfactory.

II.3.4 Project work and information skills

Introduction

The three areas of student learning with IT considered in section II.3.2 (use of IT tools, IT as a tool develop and extend learning, and developing general mental skills) may be implemented in almost all secondary school subjects in a cross-curricular way in a process of manipulation of information in specified assignments which lead to the student's development of information skills. Information skills is a concept with a wide meaning and is meant to include traditional library skills (searching and retrieving information from a library) and traditional skills of study, which emphasize reading and writing. Information skills also include skills for formulating hypotheses on what there is to know, and what questions are needed to find the answers [Irvi85].

Information skills

It has been argued that Information Technology could foster the development of and give new meaning to information skills. At secondary school level this requires that teachers give students specific tasks designed to increase or enhance learning. These assignments should have clearly-stated objectives and clearly-stated criteria for assessment, and the computer can play an instrumental or even methodological role in the student's work on prescribed tasks. O'Shea and Self argue that successful resource-based and computer-supported project work is educationally very desirable, because the students learn to pose, refine and solve problems and they learn how to learn from each other [OShe83]. Nevertheless, teachers have to make a big effort to implement project work systematically. The reason is that every student or small group has its own case that should be supervised by the teacher who has to master both subject and instrumental technology. The designer of learning materials (text books, notes or software) for support project work also faces a hard task.

This project style of school work is aimed at fostering the student initiative and the critical thinking necessary to support the move to more independent learning. This is a requirement in new curricula, like the national curriculum of UK, in which those skills are made explicit. It can only be implemented efficiently if there is specific teacher preparation, school organization, and availability of information and computing resources. In particular, information skills development depends strongly on the type of software, and on the skill and imagination of teachers, who in turn themselves become learners [Cart87].

Information retrieval

An example of school work which develops several information skills is found in the retrieval of information from databases. This is an activity in which the student can take a lot of initiative and choose directions that are interesting to him or her. Experimental research projects on using on-line databases available as professional service, such as the one described by [Irvi91], give evidence on some interesting issues:

- teachers give up their former role of information providers, and turn into guides and co-learners, with an according change in classroom management methods,
- inside the school technology can support individual and independent enquiry work, playing a real role with a well-defined purpose,
- student skills on evaluation of information may be develop at a young age,
- on-line searching stimulates language development.

This type of experience can nowadays be more widespread when CD-ROM materials, like databases or electronic encyclopaedias, or hard-disk databases, are used instead of on-line systems, but conclusions on student's learning and teacher's activity would probably be very similar. Concerning the development of information skills hypertext systems are especially interesting. These allow the student to obtain and evaluate information in a non-sequential way, while moving easily through texts, references, tables, graphs and still-pictures. The combination of hypertext with sound and video, even with telecommunication, is known as hypermedia. Developments like HyperCard permit "students to compose, illustrate, highlight, animate, and even add sound to their reports, ... students have a tool that allows them to explore and expand the horizons of the conventional classroom. Students are now required to think on multi-levels and link ideas together" [Steb90]. Information skills are no longer text-based, evolving from the ability to write reports to the skill of producing attractive visual presentations.

Conclusion

Development of information skills is a central aim of learning for living and producing in an information society. But beyond this "human capital" component, the development of information skills by the student should be seen as a fundamental right, because they are the key to open access to information, to culture and to knowledge. This right was formalized in the International Convention on the Rights of Children, which was adopted unanimously by the United Nations in 1989 [LaBo91]. Information technology has, at present, a central role in supporting this right of development of information skills in modern secondary education.

II.3.5 Availability of computers to students

Introduction

To end this chapter on students and learning we give some information on the actual availability of computers to students today. Today the microcomputer is increasingly available in secondary schools, but there are still not many around, with the result that their impact is low in general terms.

The number of computers in schools

To outline the situation, it is enough to consider a typical example. A secondary school with 500 students equipped with 10 computers, a normal situation in many schools today, means one computer per 50 students. Let us assume 25 hours a week attendance by students, then on average every student can use a computer 30 minutes per week. Although there is a variety of methods of use other than individual use, it is evident that, with such a low availability of equipment, great pedagogical progress will not be made and also that this will not suffice as preparation for an information processing-oriented society.

In developed countries the computer-student ratio is often more favourable, but even with two or three times the number of computers the situation does not permit a much higher student-microcomputer interaction. The number of computers in secondary vocational education, however, is in general sufficient to attain the proposed aims. Integration of IT in general secondary education requires a much larger provision of equipment, and this is difficult to accomplish in most of national policies with respect to IT in education. The problem is worse in developing countries and Third World countries.

Although "under-equipment" is the general rule, some advanced experiments have been set up recently in general secondary education in which the ratio of one computer per 4 or 8 students is already a reality [Sams91] [Moon91]. [Turn91] reports on Scottish experience with the effects of the availability for personal use of one laptop computer per student. The experiment monitored the effects on learning strategies, teaching styles, classroom management, and the development of writing skills, but the long-term effect of the availability of computers on the student behaviour is not known.

A personal lap top computer for every student

The solution to the problem of the availability of computers will probably have to wait until cheap, portable and compatible microcomputers, to be used as individual tools, appear on the market. It seems reasonable to expect that before long the microcomputer par excellence will be a portable one. The vision of Alan Kay at the beginning of the 1970's, which predicted the existence of the "dynabook", a computer of the size of a book, equipped with great memory and processing power, is becoming a reality before our very eyes. It is to be predicted that the progressive personalization of computers will reach education and will oblige us to rethink educational policies, methods, and student use of technology.

Conclusion

On the average student use of IT in schools Becker may be quoted [Becker91] on three points:

- "In the last five years, changes in how schools use computers have been modest, but the direction that these changes are taken is fairly clear. Systematic and regular student practice of basic skills in elementary school computer laboratories has become somewhat more common. And, primarily in middle and high schools, there has been an increased effort to use computers as productivity tools for expressing ideas and recording and analyzing information".
- "Early in the decade, computers were valued for providing highly motivational skills practice and for enriching the curriculum with the subject of "computer literacy", and late in the decade those two activities still dominated school

computer use even though the range of skills practised and the range of computer literacy activities expanded significantly during the decade".

- "Although having computers function as an intellectually empowering tool is an idea that is growing in support, actual practice among classroom teachers still lags far behind".

Some surveys have attempted to give a picture of the state of the art on availability and student use of Information Technology around the world, but many of them are partial and heterogeneous, having a variety of approaches and giving different kinds of data. [Pelg91] is probably the most comprehensive and up-to-date survey available. Other sources of information are [Beck91] [CinE91] [DES91] [Shim92] [Swin90].

II.4 School policies and school organization

II.4.1 School policies

Introduction

Until quite recently, plans at school level have not received much attention. In many cases the incorporation of IT in the classroom continues to be the result of individual actions rather than a systematic approach at the institutional level. In some cases, this "enthusiast's ideas appear to have little relation to the reality of the classroom" [Drag88] and thus use of IT seems to be the realm of a limited number of people who are particularly concerned. It has to be recognized that "the practical problems of integrating the microcomputer often defeat the most willing of prospective users, whether it be because of lack of equipment, lack of software, inappropriate room layout or over-large and under-motivated classes".

From this follows that a definition at school level of a policy with respect to Information Technology is a crucial issue, which involves specific questions. These questions concern:

- desired objectives and educational outcomes,
- human factors and the attitude and training of teachers,
- organizational measures to be taken,
- management of economic and teaching resources.

Collective decision process

Having a collective decision process on these matters is fundamental in a school which is the basic unit of educational action; it is a process to be supported by educational authorities. This process is probably the only bridge between exploration of new ideas or methods and the permanent incorporation of innovations. This incorporation requires a collaborative approach in schools, and a partnership with the Information Technology and services sector. As Ewart [Ewar89] states, in an organization, "people, structure, tasks and technology are interrelated and mutually adjusting ... and, when technology is changed, the other components have to be carefully tuned, otherwise they might adjust to dampen the impact of the innovation". This means in practice that the substantial changes in the function of schools (curriculum, instruction, methodologies, etc.) due to Information Technology require corresponding changes in the organizational structures of schools [Ray91].

Contents of a school policy

Many authors, like [CCW90] [Drag88] [Gran91] [SED87] [Weer91] and others, give their ideas and proposals for a coherent and evolving policy for IT within the whole curriculum. As the Curriculum Council for Wales points out in [CCW90], written statements of policy on IT are an essential basis for:

- effective design, organization and management of opportunities for all pupils to develop their IT capability in a coherent and progressive manner,
- clear communication within a school, between neighbouring schools, between a school and its local educational authority or local community.

Because there cannot be established a fixed policy fitting all schools, Drage and Evans [Drag88] point out that "the best way of helping is to suggest that there are certain key questions which need to be asked if the right decisions are to be made". In order to establish such a policy starting points for discussion, which have to be commonly agreed, could be the following questions:

- how to be thoroughly informed about the educational potential of information technologies,
- how to analyse carefully the impacts of IT on: curriculum, teaching methodologies, classroom organization, school organization, evaluation methods.
- how to be aware of the implications in terms of pedagogical organization, paying special attention to the need of flexible timetable and student grouping,
- how to ensure maximum benefit for the students and coherent progression in IT knowledge and skills,
- how to maintain the rate of change at an adequate and affordable level, with realistic targets and a realistic calendar for development,
- how to plan the internal evaluation of the innovation process, including indicators of qualitative success and periodical reporting on developments,
- how to look for external evaluation and assessment,
- how to report to the educational administration and schools' inspectors, according to their requirements,
- how to establish a representative IT committee involving members of all school departments and also specific key people, defining its decision capabilities,
- how to make adequate choices in order to solve the main identified problems taking into account school's resources and capabilities.
- how to establish a policy for teacher training according to objectives, needs and possibilities,
- how to stimulate participation of all teachers of the school, mainly by means of collaborative team-work and self-help,
- how to modify or redefine the job descriptions of teachers taking into account IT,
- how to co-ordinate teachers actions with non-teaching personnel, such as library and information resources staff,
- how to establish mechanisms of pedagogical co-operation and support with external organizations like foreign schools, local educational authorities or universities,
- how to relate the IT-based educational developments with the school's management information system, putting it at the service of the innovation?

Other questions, mostly concerning technical matters should also be addressed:

- how to select appropriate hardware/software equipment, while defining the amount of resources needed,
- how to follow-up the process of installing the equipment,
- how to cater for a flexible distribution of equipment inside school premises, including building adjustments if needed,
- how to decide collaboratively on software acquisition or even development,
- how to make and circulate the inventory of the school's computing resources,
- how to provide equipment maintenance and technical support,
- how to allocate funding for hardware and software acquisition, maintenance and renewal.

These lists may look impressive and even daunting, but there is evidence that, even with limited means and a limited objective, it is quite possible to obtain excellent results if there is a planned and co-ordinated school action, sustained by the whole, or a clearly involved part, of the pedagogic team. In any case, it is worth pointing out that if a school pursues Information Technology-related long term educational aims, the "successful implementation of Information Technology ... is only possible if the educational organization has an explicit policy for change" [Weer91].

II.4.2 School management

Information technology experience for school managers

Although it is recognized that there is no universal key to the integration of IT in education and that no single corporate body has the power to change things, an effective management of the educational organization at school level, based on a clear and authoritative policy, is a factor of uttermost importance. As van Weert points out, the "management has to define a clear policy with respect to goals to be achieved, and this policy has to be translated into an explicit policy for the implementation of applications of Information Technology" [Weer91]. A major difficulty in reaching that goal is the lack of preparation of school-managers in Information Technology or a very narrow and disintegrated view of the opportunities IT offers to improve both students' education and teacher's management of their administrative tasks.

A first step should be the acquisition by managers of a personal Information Technology experience that could place them in an informed position to understand on the one hand the training and support teachers need, and the other the benefits which may be gained from a school management information system which integrates all information specific to the functioning of the school. Such a first-level approach should give managers suitable preparation for the development of long-term plans which support educational computing in the school, while understanding the problems and promises of instructional computing [Beav90].

Computer use for school management

At the school management level, the use of computers usually begins with general purpose software packages for administrative tasks and some specific management programs which meet basic organizational needs in pupils records and general ledger. Planning is kept to minimum level and there is a very limited number of users. Growing confidence and continued use lead to a proliferation of applications with compatibility and organizational problems. Individual schools are usually ill-prepared to tackle this type of problems autonomously, so it is necessary to look for a solution in the wider context of the educational system, possibly at district level.

Taking into account, as [Ewar89] points out, that school is part of a complex network which is the educational system and that the management of the system as a whole requires fundamental information from all the schools, a global approach is necessary to develop a common and cost-effective management information system for schools. Satisfying these criteria, McMullan reports on a government policy designed to give schools financial and administrative management autonomy. With this aim, a MIS - management information system- "is designed to provide tools for curriculum organization and optimisation and also to provide the mechanisms for the statutory assessment and reporting requirements" [McMu91]. The experience McMullan describes takes advantage of a broad governmental view which makes it possible to develop an integrated management application software package to address both the specific aspects of the management procedures of a school, and the integration of data to generate comprehensive management information. This system is composed of two integrated subsystems:

- a business subsystem, formed by modules on: general ledger, accounts payable, purchase order and commitments, accounts receivable, property management, equipment management.
- an education subsystem, composed from modules on: pupils records, curriculum planning, admissions, examination administration, internal assessment, personnel, financial modelling, management information.

The advantages of an integrated approach like this one can be found in: (1) the increased internal efficiency of the school administration, and (2) the improvement of the school organization to give better service to students.

Concerning the first of these advantages, it can be pointed out that these follow from a well established and co-ordinated plan to tune the school management information system to the needs of the organization and of its clients. Needs which are not less complex than the ones of a medium-size company, and in general terms not proportional to the school size. Controls, feed-back and support on the implementation of the information systems may be adjusted and cost-effectiveness reached on a broad scale.

In relation to the second of these advantages, we come back to McMullan: "major qualitative improvements in children's education will be achieved when school organisational structures can take greater account of the learning needs and the consequent time tabling requirements of individual pupils". This problem may only be "addressed through complex management information systems which will actively rather than passively support decision-making".

Concerns about MIS in schools

Notwithstanding the advantages, Telem is still concerned [Tele90] about compatibility of MIS implementation with the normal operation of a school. On the one hand, management information systems are established to provide valuable support to school managers and employees, improving the performance and effectiveness of their daily activities. A variety of software tools, ranging from word processing to electronic mail, from filing systems to decisions follow-up systems are provided with these aims. On the other hand, the tools with which administrators are provided by the MIS, do not exist in schools without computers. The technical change due to the system offers the opportunity for a tightening of the authority of the manager and for a higher level of control on both the teacher and the student, that could lead to a substantial change in the school order.

Time tabling

Although any of the modules or units of the subsystems mentioned before deserve attention, we will briefly focus only on the time tabling problem. All school managers would like to have at their disposal an effective software package to solve or at least alleviate the burden of time tabling, but it should be emphasized that there are no generally accepted solutions. [Kang91] states that "no known method can guarantee optimality or practical solutions and indeed, no known method can guarantee the existence of even one solution", although there are successes "in tackling some specific problems, such as the examination scheduling problem or the classroom assignment problem".

II.4.3 IT co-ordinators

Many schools try to cope with the problem of integrating IT by appointing a school computer co-ordinator or IT co-ordinator. This co-ordinator usually is the teacher in school who is most knowledgeable about computer use, and who is active in two roles: a traditional teacher in a subject and an IT co-ordinator. The role of such a co-ordinator may vary from that of an educational leader who co-ordinates the overall computer technology program in the school, to that of somebody who works at a specific grade level, in a specific subject area or in a specific educational process [Mart87].

Functions performed by IT co-ordinators

According to Pelgrum and Plomp [Pelg91], a school IT co-ordinator is somebody with two main characteristics: (1) he or she is technically informed about computers, and (2) he or she is often responsible for the co-ordination of computer use inside the school. This technical and managerial authority is basically defined by the functions which the IT co-ordinator performs in school. These functions cover four areas:

- co-ordination of the use of the computing resources by different teachers in different areas of the curriculum, responsibility for the time-table of computer laboratories, and co-ordination of informatics-oriented subjects,
- technical support of teachers, including periodical checks on the computer equipment and easy-to-do maintenance, software installation and maintenance, and management of technical documentation,
- promotion and pedagogical support, mainly aimed at informing teachers about the availability and suitability of computer programs, and collaboration in or even supervision of teacher training,

- administrative tasks connected with the use of IT-resources, including the collaboration with the school management in planning and developing the school plan on IT-equipment acquisition, budgeting and staffing.

Although the actual implementation of these functions may take many organizational forms and may vary in intensity, it should be noted that the functions have to be performed in a systematic way if IT is to be integrated in the school activities.

The status of an IT co-ordinator

The functions of an IT co-ordinator form a time-consuming task which requires a variety of specific and often high level skills, but is not always rewarded according to its importance. It is a fact that today, in a many schools, the use of IT relies on the enthusiasm of a teacher, acting as computer co-ordinator, without an appropriate professional status. In schools which have been successful in integrating Information Technology across the curriculum, a proper IT co-ordinator is to be found, often a member of the senior management team of the school. We believe that the figure and the functions of the computer co-ordinator deserve more attention and research.

Undesirable side-effects

The activity, or the sole existence, of IT co-ordinators sometimes has undesirable side-effects which hinder the participation of other teachers in IT based innovation activities. When there is not a clear school policy for the integration of IT into the curriculum, use of Information Technology may be seen as a specialized activity, personalized in one or few teachers, unrelated to the curricular goals of the school. The very real need for specialists, prepared to provide leadership and expertise over a wide range of IT-related issues, has to be balanced with the need to stimulate and foster the participation of other teachers with different views, perceptions and interests.

Conclusion

The energy and commitment of IT co-ordinators has been and is an extremely valuable component in the far reaching process of the introduction of IT in education. It should, however, also be noted that these co-ordinators sometimes seem more concerned with Information Technology resources than with curriculum development. IT co-ordinators should have a broad view of the curriculum, and be able to understand the needs of teachers and provide support in many situations. The central role of IT co-ordinators in organising and assigning resources makes these characteristics extremely important; otherwise a conflict between technological and educational perspectives inside school is likely to arise.

II.4.4 Arrangement and management of equipment

At school level decisions have to be taken on how to physically arrange the equipment, rules have to be specified for the access by students and teachers and guarantees have to be built in that the equipment is used for school activities only. In short, it is inevitable that policies on the management of the equipment are made.

Computers in the classroom or in a computer room

Because computer equipment is scarce, most schools enter in the classical, unavoidable and worthy debate about computers in the classroom versus computers in a computer room or computer laboratory. The physical distribution of the computers in the school and the organization of their access have significant effects on the results of their use. To install a few computers or just one computer in a classroom, imposes a particular logic on the use because this is either (1) by the teacher in a demonstrative mode or (2) by a few students who use it in resource mode and work autonomously, when appropriate, according to specific group arrangements and class activities organized by the teacher. Computers placed in a computer laboratory also impose a particular logic on the use: teachers tend to decide which software has to be used, and assign students specific tasks which usually take the whole teaching period. If the computer laboratory has enough equipment to allow the use of one computer by one student, individualization of learning can be maximal, but it should be noted that "use by individuals is very restrictive in that it does not encourage the broader activities that embody co-operation and discussion" [Drag88]. Plomp and Pelgrum point out that "on class level, the computer:student ratio determines whether whole class activities for certain applications are possible. Although opinions differ somewhat, a ratio of 1:2 is generally accepted as a sufficient condition for using computers in whole class activities" [Plom91]. This arrangement permits a student-to-student interaction which is thought to be very valuable.

The arrangement of computers in a computer room also has some negative side-effects. To quote Watson [Wats90] [Wats91], who is very concerned about these effects:

- (the computer lab) "does not encourage a sense of curriculum integration",
- "the nature of the room emphasizes the hardware, not a learning environment generated by the software",
- "the physical arrangement with micros on benches around the walls inhibits the teacher-learner relationship".

A further drawback is that teachers have to schedule the use of the computer room, often in agreement with the school management or the IT co-ordinator. This poses a problem when tuning curricular opportunities to the use of suitable IT resource. A schedule which was maybe established weeks in advance, may turn out to be very misleading or even disappointing for both teacher and students. Students will think that the lack of systematic availability of computer resources is against their needs and that computer work is an add-on, irrelevant for attaining curricular objectives. It should be noted that the predisposition of teachers towards IT-based innovations may be seriously weakened by repetitive inadequacies in the arrangement and availability of resources: teachers, just as other professionals, need the appropriate environment to do their jobs properly. However, as Hebenstreit points out, the total number of computers available in school immediately influences the physical distribution: "As long as the number of computers in schools remains 1 per 50 students, or even if the number goes up to 5 per 50 students, there will be a computer room for computer practice. In that case little change can be expected in computer use" [Hebe89].

Local area networks

As was pointed out, there are many educational occasions where computers should be available in a room with two or three students working together on every microcomputer. This explains the growing tendency to interconnect school microcomputers with peripherals and file servers in local area networks. This situation is still rare, but schools are driven to it by continued expansion of computing resources and their use by students and faculty. "These systems try to provide a complex set of services addressed to fulfil a diverse set of requirements", as McLean points out [McLe88] and constitute a specifically planned and standardized infrastructure. The appearance of local area networks does not in itself imply an increase in power and availability of Information Technology resources to teachers, learners and classrooms. Networks often only interconnect equipment in the computer room, leaving unresolved the problems of access to a time-table fixed resource. It can also happen, as [Wats91] remarks, that "the way the network manager organises user access and interface will often reflect a technological perspective rather than an educational one". This easily happens when software selection is made on purely technical criteria.

Networking gets its full meaning when not restricted to a single room (the computer laboratory) and extending over all school premises, connecting (almost) all school computing equipment. In this case a sensibly managed, efficient and easy-to-use network environment could be an important asset for putting computing power in every corner of the school to facilitate attainment of pre-established educational and curricular goals.

School networks are usually implemented using standard networking software, especially if a secondary school has some activity on computing-based vocational studies. Because of their operational complexity, these may hinder computer use by teachers and students. In any case a basic training on operational procedures has to be given to teachers.

Problems of maintenance

The variety of the equipment causes severe maintenance and management problems. Many schools have been aggregating equipment and software of different standards which pose big or even unsolvable problems of compatibility. New equipment does not replace older equipment, but is in general installed beside it, making familiarization and training more difficult. This situation is even worse in schools with a long tradition of IT-related work relying on what the market was offering. Fortunately some national and regional IT plans have promoted a common technical background, provision of software and maintenance services, and teacher training. These factors, on national or regional level, help to overcome problems with equipment which quickly turns technically obsolete.

The adequate maintenance of computing equipment is a major problem for schools which often goes beyond their financial capabilities. Computers used by many individuals develop mechanical problems and heavily risk to be affected by Trojan/viral programs [Bran90]. When equipment is available in large numbers, proper maintenance personnel, for both hardware and software, is needed, but most often schools can not afford this. If the computers are networked, a systems manager might also be necessary.

Conclusion

It may be concluded that the arrangement of computers in schools is a question of conflicting interests when the number of computers is low and interest in their use high. When computers are available in satisfactory numbers, these usually are placed both in a computer laboratory and in different school locations, including classrooms and departments. It is suggested that small computer clusters are a very promising form of arranging the equipment in classrooms, libraries, resource centres, experimental science laboratories and other.

II.4.5 Information and resource centres

In their broadest sense, "resources" can be taken to be anything in the school or its environment which may be used to help teaching or learning [Davi75]. The word is, however, usually used in the more restricted sense of equipment, facilities, and materials with an informative content for educational purposes, which are available in definite locations in schools for students and teachers. School library, resource centre and media centre are converging concepts: their common aim is to organize, make available and systematize the use of a growing variety of educational resources in schools (books, journals, software, video and sound materials and other), usually under the management of staff with specific training.

When one has to cope with the "recent orientations of the educational systems (that) have given more importance to autonomy, self-instruction and personal opening-up" [Hall86], the significance (or in some cases the sole existence) of information and resource centres in schools gets a new meaning. These centres support problem-solving approaches and methodologies of project work throughout the whole curriculum.

In line with this view, the centres should become "learning laboratories" [Call87] providing a cross-curricular learning environment and offering opportunities for development of information skills, but also providing a physical work place for use of a range of materials, including computers and printing facilities. Teachers who no longer are the unique source of knowledge, but who supply guidance and assessment, should promote the use of such open-access facilities, according to an established pedagogical policy.

As it is today, school information and resource centres can be considered to be developed out of a school library and aim to deepen the connections between school curriculum and information needs of teachers and pupils. It integrates traditional sources of information (e.g.. books, magazines, encyclopaedias, etc.), audio and visual materials (video recordings, audio tapes, videodisks and so on), computer-based multimedia systems and telecommunication systems which give access to a range of telematic services, such as information retrieval services, electronic mail and teleconferencing facilities. It also offers a place for autonomous and small-group work of students on projects and assignments. It might also be a place where resources such as portable computers may be borrowed by pupils for personal use. Conceived as "an educational medium and not as a surrogate of teacher" [OShe83], the information and resources centre has the potential to contribute to develop an essential function for student learning, provided that sufficient staff resources exist in order to monitor activities, to identify and support students information needs and to implement change policies in collaboration with teaching personnel. Students working with computers, CD-ROMs and communication facilities should be a common sight in these centres. There is evidence of such use in secondary schools with large numbers of computers and the corresponding IT policies. Also specific school information and library centres which heavily rely on IT use, have been successfully developed to address heterogeneous populations of multilingual/multi-cultural backgrounds, to make possible autonomous and non-conventional ways of learning, especially of in the area of languages [Rica91]. To equip schools with such a powerful pedagogical instrument should be a priority of educational authorities at all levels; it would also mean integration of IT in education with long-term aims.

II.5 Computer hardware

II.5.1 Uncertainty and evolution

Introduction

The use of computers in education has always been driven by technological and market forces. The big CAL projects of the 60's and 70's (PLATO, TICCIT and other) relied on the use of terminals linked to mainframe computers. In the 70's minicomputers were the technical support of some famous projects such as the French experience of "58 lycées" or the National Development Programme on Computer Assisted Learning in Great Britain (NDPCAL). Since the 80's personal computers have gained dominant presence by constant improvement of performance, functionality and price, and education has taken great advantage of this development. The irregular, but notwithstanding impressive, reality of computer use in schools in many countries is due to the microcomputer.

In the world outside education, the same tendency may be seen: users of traditional mainframe architecture in many fields are constantly migrating to personal workstation-based systems which better satisfy their needs as end-users. The end-user of personal systems experiences continuously an increase in power resulting both from the progress in functionality and the favourable evolution of the cost/performance ratio.

The evolution of personal computers

The basis for this spectacular development of personal systems is twofold. Firstly, the appearance in 1975 of the famous S-100 bus (later called the IEEE 696 bus). This provided the basis for a flourishing industry of compatible subsystems. Secondly, the appearance of the IBM PC by the end of 1981. This signified the consolidation of the "bus" philosophy as an element of great flexibility in the configuration of highly specific systems. The compatible micro-chip industry which deals with the PC market based on the XT bus (8 bit), AT bus (16 bit, ISA-bus), or the EISA bus (32 bits) has tremendously grown. The uneasy way in which new micro computing cultures settled down, was the origin of a series of "de facto" standards which in many occasions dictate the freedom of planners and users of IT. In some cases schools and educational administrations have bought computers which were essentially hobby systems; they put many expectations on them which later were deceived. In general, education has followed the path opened by the computer industry, and has tried to keep abreast of technological development. However, the uncertainties in these developments, with many notable failures in the predictions of prospectors and also some ill-fated market options, have placed a strain on interested teachers and school system administrators.

Development of standards

Below follow some examples from García-Ramos [Garc90] which illustrate the uncertainties in the developments.

(1) Internal memory

The evolution of computer memory has been quite erratic. At the beginning of the 80's Magnetic bubble memory was predicted as the revolutionary memory for computers, but it never came to working well. Instead DRAM semiconductor chips, originally of 16 Kb and 64 Kb (in the era of the Z80, 6502, 8 bit microprocessors), then of 256Kb (for the 8088, 68000 and other 16 bit microprocessors) have been dominating the market. And now new 1 Mb chips and also 4 and 16 Mb chips (64 Mb chips are even being advertised) pave the way for the development of the powerful systems of this decade. The present and future demands for graphics applications with animation, enormous document processing systems, HDTV, etc., are stimulating an insatiable demand for these types of components.

(2) Operating systems

The CP/M operating system for 8 bit microprocessors found itself overnight, between 1978 and 1979, the indisputable "de facto" standard in the micro world. MS-DOS, much earlier conceived for 16 bit micro-processors, but only backed by few people against CP/M-86, only became the standard operating system of the 80's when IBM gave it its support. In the line of operating systems, there was already talk in 1980 of the imminent arrival of UNIX as the "solution" to compatibility problems. Over 10 years have had to pass, an extremely long time in IT, until, after many changes, UNIX now has managed to achieve the position of a standard for the 90's. It is uncertain how much and how soon this will affect the education sector. To enter education UNIX should be provided with a WIMP interface concealing the "complexities and obscurities it contains whilst preserving and exploiting both its flexibility and extendibility" [Whit88].

(3) Graphics

Defining standards in graphics has been a necessity in order to allow the portability of applications. Mainframe and minicomputer graphics, when available, were very idiosyncratic. Therefore courseware using graphics, developed in universities to run on proprietary systems, never reached secondary education. Some microcomputer systems used special purpose processors to execute graphics instructions and to create the video signal; others simply made available a portion of the random access memory as a bit map for video drivers [Lang82]. The CGA palette system of the first IBM PC computers was disproportionately limited in relationship to the power of such computers. Unfortunately much development work of educational programs took place with this ephemeral standard. EGA was an even more ephemeral standard and now, after a decade of incompatible systems, the situation seems to be temporarily stabilized around VGA and super VGA systems. Apple Macintosh has always had good graphical capabilities, although mostly without colour.

(4) CD-ROM

Concerning optical disc storage, CD-ROM was advertised in 1985 as the solution for cheap static mass storage; it was technically and commercially made ready in record time (by the end of 1986). The prospectors failed, however, when they predicted that by 1990 there would be more than 10 thousand editorial titles on the market. Fortunately, the technology was relaunched in 1989 and at the moment there are about one thousand titles (one tenth of the prediction) with more appearing all the time, some of them developed in conjunction with emerging multimedia technology. WORM (Write Once, Read Many) optical discs have been introduced according to the predictions of 1988 and 1989, but without a clear standardization policy. Soon the relatively new technological development of re-writable optical discs will change everyone's plans on WORM technology. Dropping prices of optical discs could facilitate its use in educational settings.

(5) Videotex

In the grand public arena, great possibilities were announced in 1981 for the videotex system as a means of boosting consumer data transmission, based on the increased success of these systems in France, England and Germany. The only country where this system really got off the ground was France. This telecommunication system, conceived before the advent of microcomputers, is being used educationally in some countries but is technically almost obsolete.

Factors in technological uncertainty

Education has almost always sought standards on which to base its activity, thereby giving a common basis to training and software development. But it also ignored or forgot that standardization by agreement of independent, professional committees is superseded by the "de facto" standards obtained by predominance in the competitive computer market. Any present or future IT policy in education should remember that in IT there are many extra-technological factors which significantly change the possibilities of the appearance and consolidation of new technologies. Among these factors are:

- the interests of the market,
- the struggles between big multinationals to put themselves in a good position,
- the war of the setting of standards,
- the predominance of a few IT cultures (IBM PC, Macintosh, etc.),
- sociological and economic factors,
- the availability of a wide range of attractive and powerful software tools.

In the case of the education sector there is also the influence of the policies of public and to some extent private institutions, capable of influencing the whole educational community. National plans on computer use in education have sometimes been closely related to national policies on hardware development, with the aim of supporting local Information Technology industry. During the 80's and in certain countries, funding schemes have been available to schools provided that they spend the money choosing from a limited range of nationally produced microcomputers. Examples of this approach were to be found in the United Kingdom, France and to a lesser extent in countries like Denmark. Such policies, called by O'Shea and Self "chauvinistic schemes in hardware and software development" [OShe83], have many times gone against industry international trends and market developments, creating educational computing cultures, which, although well developed and self-sustained, remain isolated in the continuously more standardized Information Technology market. When examining these national policies, it is surprising to see how many expectations arose from the delivery to schools of home and hobby computers and to verify that there are striking differences between those computers who still give service and those who died very early. Besides the nationalistic component of the school's hardware provision there was also the concept that "cheap systems" are good enough for education. The use of computers with little capabilities, compared with those available in the mainstream market, put some educational plans in hazard, prone to disinterest of teachers and technical obsoleteness.

The future

Fortunately, the tendency of educational systems to adopt policies based on a few real standards has been growing world-wide in the last years. In these years the informatics industry has evolved towards a stabilization based on a handful of standards for workstation architecture, operating system platforms and connectivity protocols. Hardware performance is continuously increasing and, according to Vergés [Verg92], "the real standards battle is moving to high level application programming interfaces and facilities that provide a single, programmatic interface to applications, while often managing multiple lower level standards. The emergence of these software technologies is essential to smoothing the system interface for developers and users". Educational plans on hardware and software should always take into account these momentous realities.

On the basis of the increase in performance and the current developments in standards and in the market one may predict that at some time in this decade the usual workstation for many students in developed countries will be a powerful microcomputer with large dynamic memory (8, 16, 20 Mb) and a very fast central processing unit (33, 50 or even 200 MHz), with very vast and very fast hard-disk storage (from 100 Mb to 1 Gb). Cheap colour printing will be available. Standard networking facilities will be available with a speed of over 64 kbits per second, allowing powerful file transmission. Visual interaction will be supported by high resolution screens of 1 million pixels with colour of almost photographic quality. Input/output sound/voice peripherals will be available and integrated in many application packages. These factors, together with interactive optical disk (600 Mb - 1 Gb) with read/write possibilities, will characterize a hardware scenario using astounding interactive products from a market of multimedia storage-intensive applications.

II.5.2 Peripherals and emerging technologies

Peripherals

At present, it can be said that computers are often the focus of interest, pride and funding of the schools. But schools have to be aware that availability of specialized peripherals is of utmost importance. Secondary schools must have a varied provision of peripherals to satisfy the wide range of applications needed within a curriculum in which IT is integrated.

The most obvious peripherals are general use printers, colour printers and high resolution colour screens. This type of screen should not only be used in activities involving graphics, but should be on every computer. For graphic expression and design it is also necessary to use plotters, scanners and digitizers. Alternatives to the keyboard, such as touch screens, joysticks and overlay keyboards should also be available for use by small children and for special education applications. The list of peripherals should also include: data collection instruments for science experiments and interfaces, external devices for control technology, optical mark readers, MIDI interfaces, instruments for musical expression. And also telecommunication equipment for the many telematic applications which for the first time allow schools to comfortably expand beyond the limits of their walls.

Local area networks should be used to share (1) information resources like high-volume memory units such as fixed discs and CD-ROM units, and (2) service peripherals like laser printers.

For a thorough discussion on educational peripherals, see [Will88].

Emerging technologies

As emergent technologies the Multimedia PC (MPC) and Digital Video Interactive (DVI) multimedia technologies can be mentioned. These imply convergence of the informatics market and the consumer electronics market in which many big (and small) companies are taking positions.

MPC is a sound/voice add-on onto existing PC functionality in a WIMP environment (Microsoft Windows), which together with sound board and sound/voice peripherals may integrate CD-ROM. This is precisely what gives MPC a big educational potential. Launched by the end of 1991 it has driven an impressive growth of marketed products in the areas of information resources and entertainment, giving new dimensions to 2 or 3 years "old" products such as electronic encyclopaedias, geography, maps and atlases, fiction tales, foreign language courses and many other.

DVI technology enables real time digital full-motion video and audio to be compressed or decompressed, stored on hard-disk and played on 386/486 microprocessor-based computers, along with graphics, still pictures and text. The power of this technology raises expectations about a great increase in the volume and rate of application development in key markets including training, education, information retrieval, desktop presentation and entertainment [CinE90].

The combination of the compression and decompression facilities of DVI technology with the storage capacity of optical discs makes digital multimedia computing possible. The future encounter of these two technologies, at an affordable price, could satisfy the most inspired dreams of the ancient and pioneer educational media developer who was using rigid mainframe computers only 20 years ago. The emerging technologies mentioned and others like CD-I, together with the growing power and availability of laptop and notebook microcomputers, will probably bring an entire new wave to computers in education characterized by the empowerment of the learner.

II.6 Software for education

II.6.1 Types of software and market issues

A diversified and integrated use of Information Technology in schools requires a wide availability of computer software. The software used in secondary education may be general software produced by software companies for the microcomputer market, or may be produced and marketed specifically for an educational use.

Industry standard applications

The first category of software consists of industry-standard application programs, such as word processors, spreadsheets, database managers, communication managers, integrated packages, desk-top publishing tools, hypertext software, programming languages, statistical packages, etc. These applications are being used by many secondary education students as working tools in their assignments or are used in classrooms under teacher supervision. Schools should choose a small number of these industry-standard general purpose programs on criteria of compatibility and of optimal user-interface. Sound and stable school work and teacher training can be based on these tools. The latest market novelties should not be the decisive factor in decisions for acquisition of these programs, because there are serious implications for the school's IT-based work.

The general software market also provides many specific tools, that is, software tools aimed at working, exploring, researching, or playing in certain domains, in which the user is responsible for the content or data that the program handles. Programs of this type are: modelling and simulation packages -including games-, drawing, painting and design programs, experimental data acquisition and control technology modules, music editors and players, amongst others. This software may have been produced both for professional sectors and for the school and student market.

Educational software

The second of the software categories is the so-called "educational software" (no better name seems to have been invented so far), which means that this software has been designed, produced and marketed specifically for educational use. This software may be subject-specific, within a wide range of instructional aims, or may be independent of domain, acting as a framework that should be filled with contents adapted to particular subjects and to specific students' needs. Educational software may be marketed as an individual program dealing with specific subjects, or as a series of programs systematically covering a wide area of educational content.

Particular groups of students (young secondary students, or low-ability pupils, or students with special needs) should be able to do - maybe with some limitations - the type of information processing that the industry-standard general purpose programs allow, but complexities and sophistication may hinder use. In that case the educational software industry can provide tools similar to industry-standard application programs, but tailored to satisfy specific groups and levels of students.

Under the heading of educational software, collections of hundreds or even thousands of, usually small, programs can be found in some countries. Hunter reports that in the USA individual software packages intended for instructional or educational use in schools and at home are purchased from about 900 commercial suppliers, and that in 1989 there were more than 10,000 software products on the market. Besides individual programs on floppy discs, there are also: "'integrated learning systems' which include curriculum software for multiple grade levels and multiple subject areas, instructional management software and a networked set of computers, usually installed in one room" [Hunt89].

Commercial versus non-commercial educational software

Some say that from government plans originate software developments of quite different styles than from private initiatives. The need to obtain economical gain leads commercial producers to seek short-term returns by means of marketing popular programs whose suitability to secondary education is by no means guaranteed. [Haug89] indicates that, in contrast, national plans on IT can have a more long term view on educational software: "government driven production can aim further ahead for what is thought to be needed in future. Thus it has been possible to promote development of tools for the creation of new software, to make these tools open-ended and flexible; letting the teachers use them according to their own wishes". Policies of this type, leading to the availability of a limited set of high quality programs have been implemented with success in some countries [Boll90] [Vass91].

New developments

A whole new category of programs for secondary education use is at present coming on the market. Development is stimulated by growing availability of multimedia technology, new and very powerful development tools, and the standardization of computing equipment. Multimedia technology, which is a mix of personal informatics and consumer electronics, serves a mixed market: educational materials, audio-visual electronic media, and personal computing. Packages which are now coming on the market seem to be addressed almost indistinctly to leisure and entertainment, to educational and to professional clients. It is therefore to be expected that they will be found in secondary schools in the near future. These packages which will be further enhanced by coherent pedagogical integration of educational software, CD-ROM reference materials and school books, will bring about a major change in the educational software market. Another future challenge to the educational software market is to satisfy the needs which will probably follow from availability of laptop computers for personal learning by the students.

All these factors (type of software, market offer and trends, government policies, industry struggles, evolution of standard) are to be taken into consideration when trying to make the right decision on educational software. Schools trying to implement a IT-policy and fulfil their IT-needs, could easily be deterred by a feeling of chaos. It should, however, be remembered that diversity brings enrichment. And also that the interplay between government which strives to unify, and private initiative which offers diversity, will bring advantages in the long run.

Conclusion

It has to be stressed that, notwithstanding policies and market issues, the integration of IT in education depends heavily on the judgement of teachers, who should evaluate programs carefully in order to be able to use them in the classroom with confidence (see [OECD89] for background information). Large numbers of programs, produced by a multiplicity of suppliers, are difficult to systematically evaluate by teachers through lack of time and lack of knowledge of formal evaluation techniques. Also Heller [Hell91] points out that software has to be reviewed by someone actively engaged in the specific discipline, and that there are no publishing vehicles for peer reviews of educational software, nor is this activity rewarded at all.

II.6.2 Software development

Introduction

The evolution of software development in the microcomputer era is summarized by Moonen in three phases: "At first courseware was mainly developed by individuals. As a result each such individual had to be a specialist in at least three areas: subject matter, didactical approach, and programming. Later a multi-disciplinary approach was used incorporating the different specializations in a more appropriate, 'professional' way ... Finally, an 'industrial' approach was recommended, mainly to strengthen project management of the development and production efforts in order to improve cost control and time schedules" [Moon89].

As teachers were to take part in these developments, authoring systems were on the agenda of many concerned teachers. Rushby points out that this involvement was based on two questionable assumptions: firstly, that teachers and trainers need to be able to write their own programs, and secondly, that they need special tools to enable them to do that [Rush92]. Teachers who developed software usually did not feel compensated for their efforts from an economic point of view, nor by recognition in their professional life [Hell91]. These factors, amongst others, had as result products which were more hand-crafted than professional, and whose suitability to student learning was often hard to demonstrate. Even good ideas were bound to be mis-implemented because of the insufficient investments attracted by a small or poor market. Nevertheless, many well-planned and stable projects for software development have been undertaken during the 80's in countries were there was a deep concern over software for education, often in relationship with stimulation plans of IT in secondary schools. These projects, mainly carried out under governmental initiatives or university leadership and sometimes by private software companies, mainly in the USA, pursued developments in two directions [Moon89]:

(1) development of courseware fitting traditional didactic approaches, not too complex to use, and to be modified by inexperienced teachers, (2) development of teacher tool kits enabling modification of partial products to fit the needs of a specific target group.

The increasing availability of computers and the adoption of policies for the integration of IT into secondary education are creating a favourable atmosphere for more professional approaches to definition, implementation, testing, documentation and marketing of educational software.

Current trends

McLean, in his "Megatrends in Computing and Educational Software Development" [McLe89] gave 13 headlines as clues to understand the evolution and perspectives of educational software development. He grouped these 13 "megatrends" under four categories of "megatendencies" which outline the development of educational software:

(1) progressively sophisticated computer environment,
(2) functional designs oriented towards dynamic visualisation, initiative lying with the user, and the integration of different media,
(3) users or learners with increased sophistication and critical attitude, who require tools more oriented toward processes than results, and
(4) structured development methods and processes with strict quality control and good support materials.

The realization of these tendencies by software developers is made possible by new software development tools currently available on the software market, which constitute valid alternatives to authoring languages and offer almost everything that could earlier only be dreamed of even in the most powerful authoring systems. Present-day programming languages and development tools provide powerful algorithmic and modular features, extended data types, access to low level functions, graphic primitives, sophisticated media editors of multimedia environments (audio, video, graphics, text) with multiple-image sequencing and concurrent animation functions. They control a variety of peripherals and storage devices, including touch-screens, CD-ROMs and videodisks. They also offer a window user interface - WIMP - with pull-down menus and interactive WYSIWYG screen layout, customized composite icons and menus, and visual approaches to programming which make the pointing device (mouse) the universal input tool. The standardization process of the Information Technology industry which we already discussed earlier, offers software developers portability of applications which earlier was impossible due to differences between operating systems, graphics standards and hardware platforms.

Issues in portable software

In educational software aimed at international markets, software producers should provide facilities for multilingual software development. Software development in English and other major languages should be so designed as to ease, technically, culturally and economically, translation of the product to minority languages, almost on release of the initial product. Such an approach could develop a viable, global educational software market by adding together the international consumer potential grounded on technical standardisation.

Another point is, as Vergés emphasizes, that the most important character set for personal computers, the American Standard Code for Information Interchange (ASCII), is not enough for the needs of computing, to say nothing of the needs of minority language users. This standard, based on one-byte character sets, leaves out many symbols such as accents over consonants, diacritics over upper-case letters, and many letters of specific national alphabets [Verg92]. A more comprehensive character set would solve these problems and could lower the cost of producing multi-version software for extensively used languages and for minority ones. It is expected that the UNICODE project (ISO 10646) will technically pave the way for solution of these problems.

Focus on the learner

As we have pointed out society puts much weight on the general aims of IT in secondary education and also on development of information skills. This does, however, not imply that development of educational software for learning is no longer a valid activity. As early as 1980, it was pointed out that the antagonism of tool and problem-solving advocates against CAI programs could be understood "as a reaction against the trivial use of computers as electronic page turners" [Niev80]. One can also say that this trivial use followed from the focus of the software. The focus was on the computer and not, as is needed, focused on the learner as an autonomous agent. According to Kristjánsdottír [Kris89], the learner should "regard himself as an active controller of his learning process", so software developers should create programs aimed at establishing a meaningful dialogue with the computer (not compulsory commands, no page turning) taking into consideration effects of human computer interaction on learner performance, developing awareness of different strategies for solving problems, and fostering collaborative work and communication between students. In particular, developers should not take it for granted that programs will be used in an individual mode in a computer laboratory.

Artificial Intelligence

Parallel to developments commented on so far, and quite independently, Artificial Intelligence (AI) has been applied in secondary education. AI techniques permit to set up a database of facts and rules over an area of knowledge, to build a model characterizing the learner and to develop a teaching process on this basis. These teaching processes then are natural language dialogue processes. The task of such "intelligent tutoring systems", in the words of Aiken [Aike89], is: "The computer tutor assesses the student's level of understanding, detects misconceptions, and seeks to remediate them by engaging in an on-screen dialogue with the student". Nydahl thinks that, at present, "these systems are fairly rudimentary and handle quite trivial pedagogical problems" [Nyda88]. The current educational approach of AI seems to lie mainly in the construction of simple expert systems by teachers or students using tools like Prolog, or in the analysis of expert system shells in computer courses.

II.7. Secondary education and telecommunication

Computer-based telecommunication covers a large technical and economical domain which thoroughly affects life in our society. Commercial enterprise and government would be crippled without the combined power of computing and telecommunication. If we look at the aspects of significance to education, computer-based telecommunication may conceptually be divided in two major strands:

- computer-mediated communication (CMC), in which the focus is on person-to-person communication or on transmission and sharing of information between members of an interest group,
- information retrieval services (IRS), in which the focus is on database access to retrieve information under specific personal criteria.

Computer-mediated communication

CMC services may primarily be either one-to-one (electronic mail), one-to-many (distribution lists or bulletin boards), or many-to-many (news or conferencing systems) [Quar90]. Electronic mail, which is the most common of these services, allows an individual user to send a message to another user, or a group of users, which is defined in a mailing list. The mail facilities often support mailing lists to which one may subscribe. In conferencing systems, one copy of a message is kept per host rather than one per user as in E-mail. Conferencing systems allow automatic separation of messages into categories by topic, and often provide sophisticated user interfaces to display lists of categories and lists of subjects of messages per category, and to select and send messages. Usually they operate in a batch mode that does not require simultaneous communication. File transfer facilities may be used to obtain or deliver any type of computer files, also allowing software distribution.

Information retrieval services

Information retrieval services originated from the information industry and were designed to cope with the specialized information needs of industry, business, research centres and professionals. These services require a powerful infrastructure of information providers, specialized tools, such as thesauri, document database systems, vendors and clients in order to survive in the competitive information market. Databases for the education sector have usually been sponsored by governments or international bodies. The most successful example of an information service for education is probably the database ERIC sponsored by the United States government, which has an impressive amount of documents covering all fields of education.

Applications of telecommunication in education

In comparison with computers themselves, computer-based telecommunications are relatively new in secondary education, only receiving a lot of attention in recent years. The benefits that secondary education can obtain from the use of IRS and CMC will mainly lie in collaborative student learning, in teacher training, and in the satisfaction of information needs. The following four cases will be considered:

(1) Information retrieval and teachers,
(2) Information retrieval and students,
(3) Computer-mediated communications and teachers,
(4) Computer-mediated communications and students.

(1) Information retrieval and teachers

Information retrieval services can give teachers fast and easy access to suitable and up-to-date resource materials to be used in the preparation of lectures, in curriculum development or in research activities. In order to use these systems teachers should acquire information searching skills which later may be transferred to students. Commercial information services are not usually aimed at satisfying teacher needs, nor is the cost affordable to many schools, so educational systems and governments should provide these types of services to help teachers cope with the demands which curriculum development and school restructuring processes pose. CD-ROM technology can be a valuable alternative or a complement to on-line databases.

(2) Information retrieval and students

Some experiments have been carried out on the use of telecommunication systems to develop student information retrieval skills (see section II.3.4) using project work methods. CD-ROM discs and databases stored on hard disk, when available, will permit a more relaxed and comfortable development of these skills at lower costs.

(3) Computer-mediated communications and teachers.

In-service teacher training is mainly developed in the form of traditional courses held in computer rooms. An alternative way to provide continued teacher training to a growing number of teachers is in the form of courses mainly delivered by specifically developed self-instruction materials, and tutoring and peer-dialogue supported by electronic mail and computer conferencing systems. In this way teachers can take advantage of distance education procedures and methods, while keeping the human interaction and support of traditional in-service courses. A combination of distance education with attended lectures can blend together the most positive features of both systems. Experiences in this area are described in [Davi89] [Gray89] [Legr90] [Maso89] [Ruiz92].

(4) Computer-mediated communications and students

Specific curricular objectives can be attained through electronic mail and tele-conferencing activities. These permit students to project and share their learning beyond classroom walls and increase their motivation, foster group work and discussion, and stimulate writing and communication skills. Such activities require the interplay of different schools, maybe from different countries, working on specific subjects. The main difficulties are not involvement of students, but the definition of the activity and its pedagogical aims, and the co-ordination and follow-up.

Future developments

The power which computer-based telecommunications may bring to secondary education has yet to be realized. Some authors are enthusiastic: "... initiatives in computer networking ... we believe have the potential to radically transform for the better both our education systems and our global society" [Cumm90], while others seem more sceptical: "although there would seem to be some interesting possibilities for pedagogical developments that could take place in network environments, these possibilities have scarcely been touched" [Bork89].

Probably the most important issue in the use of computer-based communications in secondary education is the development of a community of educators aware of the potential, and willing to take advantage of the new forms of communication that technology brings to them. Riel [Riel89] states that "the evolution of local, national and international electronic communities requires attention to group organization, group dynamics and educational leadership". A second crucial issue is to integrate fully the use of telecommunications with students curriculum and school policy, so that it is perceived as a meaningful activity and not just as an expensive gadget for trivial messages or artificial activities [Upit90]. In this respect La Borderie [LaBo91] points out that "it is not enough merely to bring the ability to communicate at a distance into the classroom. It is even more necessary that the partners in the educational system should be able to integrate this ability into their current activities, and should take the time to do so".

Computer-mediated communications may provide new channels and expand the communication horizons of small linguistic communities and of schools dispersaly located in large geographical areas. Some examples of this type of educational networking are DIN-basen (Danish), KONTI-project (Norwegian), TEJO (Portuguese), XTEC (Catalan) [Verg92], and IRIS (Québec). Projects like Campus 2000 (UK), K12Net and Kidsnet (USA), are more general examples of a wide use of educational networking. McAnge [McAn90] gives a comprehensive survey of American educational computer networks, and [ETAS91], [Fein89] and [OTA89] provide valuable information concerning educational networking. [Veen92] gives a comprehensive account on the use of telematics in a single country (The Netherlands) in ambitious as well as in small-scale projects.

Conclusion

On the basis of the potential of computer-mediated communication systems, of the need to deliver education and training to growing populations, and of the already existing activity, it may well be anticipated that every school and educational system will someday have a distance learning component, and that distant resources will be available in the place and in the moment where and when they are needed. Current secondary education telecommunication activities, though preliminary and difficult to accommodate in the school schedule, in teaching methods, and in student learning practices, are setting the way for this future.

More information on the topic of Telecommunication and Education will be given in the IFIP Working Group 3.1 Guideline of Good Practice on Tele-learning (in preparation).

II.8 Funding and cost-effectiveness

Funding

An OECD study of 1986 stated that many OECD member countries had a political will to introduce Information Technology into education and "how few are the countries where governments have taken long-term commitments in terms of their responsibilities as direct or indirect providers of guidance and means" [OECD86]. In a survey by the Office of Technology Assessment (OTA) meant to identify barriers to increased use of technology, almost two-thirds of the U.S. States cited lack of funds as a serious problem [OTA88]. Stefanko and other quote an OTA May 1988 study revealing that education "has by far the lowest level of capital investment (another name for buying technology) of any major sector, only about $1,000 per employee. The average for the U.S. economy as a whole is about $50,000 of capital investment per job" [Stef90]. These facts reveal that lack of funding is a major problem to further advance in the integration of IT, although in some countries wide ranging plans have benefited from continued economic support.

Maybe the two major problems that hinder getting funding (at all education levels) are:

(1) the difficulty to define with precision the costs involved in using IT, and

(2), even harder, to quantify the benefits that should derive from the financial support given to the technology and the corresponding implementation process.

Cost effectiveness

On the side of costs, it was already shown in the 70's that CAL and CMI (computer-managed instruction) always lead to an increment in cost. Studies like the one carried out to evaluate the costs of the mainly university-oriented and mainframe based British NDPCAL Programme, discarded the idea that the computer could lead to a lowering of educational expenditures in the part of teacher's salaries or laboratory equipment [Fiel78]. They showed that lowering of costs could only be possible in industrial training, mainly by reducing training time.

Almost by definition secondary education cannot argue that the schooling period itself or the functioning costs of schooling could be reduced by the proper use of Information Technology. Even asserting that many people need improved education could be counterproductive for the technology, because the budget assigned to informatics comes from public sources in competition with other needs and projects, which may also demonstrate efficiency and benefits. The general economic context in which education develops itself, is not very stimulating; referring to the United States [Stef90] states that "education and social work tie for the dubious honour of being the most labour-intensive business in the economy, with labour costs equal to 93 percent of output value".

To revitalize secondary education technologically according to society and student needs requires flexible and steady funding on Information Technology. At district and national policy levels, administrators often only feel committed to purchase and install computer hardware at certain politically opportune moments: without long-range plans to guide the development of innovation, "invisible" elements such as teacher training, software, curriculum and support policies are disproportional in lack of budget or even not funded at all. Even important economic considerations such as "depreciation of capital equipment and the opportunity costs of new technologies are neglected" [OTA88].

School level

At school level, the purchase of computers usually represents the main investment cost, but schools having installed computers then face the problem of setting up budgets to satisfy IT-related expenses in a permanent way. The use of computers is conditioned to a supply of software and to other collateral expenses which will be there as long as the computers are there. For schools money "isn't the only issue, but it is as real as any other, including issues of content, pedagogy and technology" [Lin91]. Without the extra money that computers need, a wide integration of IT at a school level will never be reached.

On the benefits side of IT, some cost-effectiveness models have been proposed for evaluation, but these do not give real answers: "comparing costs of traditional and technologically-based programs usually fails because the goals and objectives of programs differ substantially" (Marcia Linn, quoted by [OTA88]). Pre-test and post-test scores, experimental and control groups and diverse statistical techniques and other methods were tried extensively during the 70's and early 80's, mainly in the United States, to measure the effectiveness of computer-assisted learning and computer-managed instruction materials. As early as in 1980, Aiken reported that "since so many assumptions are made and so many variables are uncontrolled (teacher differences among the most important of the latter), such statistical results tell us little. More promising, therefore, are attitudinal studies measuring factors such as changes in students' study habits and attitudes" [Aike80].

Conclusion

Computers introduce a whole new educational situation, with revised roles and new responsibilities for both teachers and students, with short-term effects on attitudes, knowledge and skills of, again, both teachers and students, and long-term effects which are scarcely known. Additionally, experience has been gathered on technology introduced mainly as an add-on to traditional curricula, but not on more global, new approaches to IT-based learning skills and student competence.

The inability to demonstrate quantitatively the educational benefits of IT could be very risky for innovation in times of financial constraints in developed countries. Nevertheless, the evidence of societal needs and the convergence of recommendations of competent international bodies, together with other factors commented on in Part I, may fuel the progress toward shortening the "learning enterprise's technology lag" [Stef90] and realize new aims of education.

II.9 Equity issues

The uneven penetration of Information Technology into secondary education implies non-uniform student access across the education system. Cummins and Sayers affirm that "the implementation of ... educational technology has been accompanied by major discrepancies in equity; that is, in the relative degrees of access, participation, and benefit enjoyed by particular groups of students" [Cumm90]. An OECD report [OECD86] states that "the response of education to the new IT is marked by a degree of inequality towards its clients".

In a given educational system, educational equity regarding Information Technology is a broad concept which embraces specific, often interrelated issues, such as:

- gender differences in attitudes, opportunities and involvement,
- students with special needs, and
- differences due to socio-economical status, which often have a close relationship with social minorities' problems.

We are going to give some hints on each of these specific equity issues, but it should be remembered here that this will be the subject of a specific IFIP WG 3.1 Guideline of Good Practice on Equity and Social Issues (in preparation).

Gender differences

Gender differences in IT-related attitudes, opportunities and involvement at secondary school level form a growing concern. These differences deserve special attention in research and in teacher awareness. They should be addressed in teacher training, at school and even at national levels. In some countries policies are already being developed. The roots of gender differences are to be found in the way society divides work according to gender and in different academic orientations according to gender. With regard to work, the OECD [OECD86] indicates that in advanced economies there is a rigid division of work according to gender, and a "concentration of new technology on the male side of the dividing line". That is, "female employment prospects depend heavily on personal services, while the growth of IT-related occupations is largely a matter for males". Concerning academic options, the IT-related gender inequalities "grow along the familiar line dividing the sciences from the humanities".

In almost every country reported by the IEA "Computers in Education" Survey of 1989 [Pelg91] computer use in schools is male dominated; this is only a particular case of the "underparticipation of females of all ages in technology-related programmes" in schools [OECD86]. There is also evidence for big gender differences in the use of and knowledge on Information Technology both by teachers and students, which, "within a context of general rise in computer awareness, indicates a lack of progress on gender questions" [Durn91]. Jensen and Klewe, reporting on the results of three Danish investigations, state that "the differences are not so great in the intermediate grades. But they increase with the age of the pupils. The results also show that the boys' advantage is especially increased by the fact that it is boys who acquire home computers" [Jens89].

The gap between genders seems to widen by age. Young pupils, girls and boys, show equal aptitude for IT in class, but during the years of adolescence, girls make negative choices on IT under the influence of its male image. Society supplies fuel for these choices by not offering many Information Technology-related jobs to women. In the schools teachers reinforce the male image of IT with out-of-hours computer clubs, usually dominated by boys, in which many girls lose their motivation to work with computers because boys perform far better. Additionally, parents tend to buy computers mostly for their sons; according to a comparative study on 16-18 year-old youngsters, carried out between 1986 and 1989, "males (were) more than two and a half times more likely than females to report using their own computer" [Durn91].

On the whole, there is a negative self-reinforcing situation which cannot be overcome by secondary school alone. The secondary school should create equal opportunities for boys and girls, and establish some compensating policy, but this seems a token gesture in view of the deeply entrenched sex-biases. Some argue that, in the context of the educational system, the best way to contribute towards overcoming the gender differences on IT in secondary education is acting in primary education. If microcomputers are widespread in primary schools and fully integrated with the classroom activities, the current "male-computer" association in pupil's minds may begin to disappear. Female teachers, usually the major part of teaching staff in primary education, should pay attention to gender differences. To accomplish this goal it is necessary, nevertheless, to begin reversing the current situation pointed out by [Pelg91]: "In most educational systems computer using elementary schools have a majority of female teachers, but most of them have only a small percentage of female computer co-ordinators".

It is also important to stress that teachers are usually not aware of the differences in learning style between boys and girls. Research results show that, if teachers are able to cope with such differences, girls like to use the computer more and as a result learn better.

Additional information on this topic can be found in [Brui92], [Love91], [Makr92], [Mart92], [McDo90], and in the proceedings of the IFIP TC 9 / WG 9.1 Conference on Work, Women and Computerization [Erik91].

Students with special needs

Students with special needs present many problems because of the wide variety of disabilities and disorders. Secondary education does usually not have to cope with mental handicaps, but only with students with physical disorders, like cerebral palsy, visual impairment or other sensory impairments. Such students may immensely benefit from the incorporation of specifically tailored hardware interfaces and customized software on microcomputers devoted to their own personal use. IT permits these students to develop following the school curriculum (enabling, for instance, written composition and mathematical manipulation) and gives them greater access to information. The emphasis on IT use should be placed in overcoming the communication barriers such students have which are the cause of many types of retardation and disorder. IT can be invaluable in reducing or alleviating the constraints such students suffer, in enhancing their well-being, in easing their emotional strains, and in improving their participation in school life.

Gifted students, on the other hand, can get a lot of advantages from working with computers on assignments and problem-solving. Kirby et al. indicate that "special education and gifted students have greater access to computers than regular classroom students" [Kirb90].

Socio-economical status/minorities

Socio-economical status decides whether computers are available in schools and the type of exposure given to students. With regard to exposure to computers, Martin reports that "Students from lower economic backgrounds are more often exposed to computer uses in which the computer controls their actions, such as drill and practice, while students from higher economic backgrounds are more often exposed to computer uses in which they are in control of the computer" [Mart91]. However, the most common problem is that economically disadvantaged students have less opportunity to perform IT-based educational activities because computers are lacking in their schools and because their teachers are not properly trained or motivated, or simply have to spent their time on social functions.

A common characteristic of the three aspects of equity mentioned is that Information Technology has a differentiated impact on sub-groups (girls, special needs, socio-economical status) of secondary education students, varying widely within schools as well as from school to school and affecting both student access to computers and the quality of their exposure [Kirb90].

A perspective on the future

In this paper we have tried to summarize the issues which are crucial to the sound integration of Information Technology into secondary education. It is our belief that, at least in the developed countries, we are now at a turning point: a move from a first phase of development to a second phase of integration. In the first phase, characterized by an evolution from teaching about computers to teaching with computers, technological developments were well in advance of educational applications and time was needed for new learning methods to prove themselves and to take root in the classroom. Some strong influences on the first phase were:

- government legislation and the aspirations of policy makers,
- a need for better education, tuning student learning with society needs,
- commitment of teachers to innovative methodologies,
- increasing interest in records of pupil assessment,
- dramatic decreases in the cost and availability of hardware, enabling teachers (and some pupils) to acquire their own powerful tools,
- simpler-to-use software environments and facilities,
- greater use of computers for school management.

What will distinguish the second phase of development is that the power of Information Technology will be put into the hands of the learner; in a way the learner will be liberated and Information Technology itself will be built into the contents and methods of academic subjects.

In the second phase of development a computer has to be always available to you as a learner, both at the school desk and in the home. Education as such is not fully in command of such developments which require a new socio-institutional infrastructure and a wide availability of personal computing tools in a stimulating and equitable school environment, free from restrictions of access and of curriculum constraints. However, the over-all adjustment of society to technological change is already mirrored within secondary schools which have to provide answers to the cultural, social and personal issues raised by that technology. The process of change will be a slow one: "technical changes rarely translate into social transformations in the short term, particularly when they concern radical or generic innovations" [OECD88].

In the process of social transformation brought about by Information Technology, education should provide students with the opportunity to master this technology while still at school, under the guidance of teachers who will guard against extremes and ensure that the main benefit is to the learner. It is also essential that young people learn to use new technologies, not to threaten the quality of life in modern society, but to enrich the relationship of mankind with his environment.

Appendix

Focus group reports from the IFIP WG 3.1 Working Conference "Impacts of Informatics on the Organization of Education", [WG3.191].

FOCUS GROUPS

Edited by J. D. Tinsley

Introduction

To help delegates to share experiences and to prepare a conference view on key issues of concern, five focus groups were formed with a remit to consider questions posed by the Programme Committee. The following reports are the outcome of these discussions which took place over four days of deliberations interleaved with other conference activities. It is hoped that these reports will contribute to the thinking and planning of policy makers at all levels and help with the formulation of future information processing strategy in support of learning development.

Focus Group One: Societal and technological influences

Questions for consideration

The following questions were considered by this Focus Group:

a) New technology is empowering individuals: how does this affect their role as members of a national society?

b) Will the family be the key future influence on schooling and attitudes to learning?

c) Are international trends influential in modifying the role and function of national educational infrastructures?

Participants

The following persons participated in the work of the Focus Group:

Alison Griffith, Rolf Kristiansen, Frank Nicassio (Rapporteur), Morten Paulsen, Viera Proulx, Paul Resta, Taskshi Sakamoto, Helmut Schauer (Chair).

Discussion summary

Complexity and promise

The relationship between human societies and technology is exceedingly complex. Modern telecommunication makes it possible for the resident of one country, for instance, to complete the formal schooling requirements of another country even though those requirements may not be accepted within their own national borders. In addition to making more complex what we mean by education, new information technologies hold promise for empowering the individuals of a society by enriching their options for communication, by extending their ability to visualize and model concepts and processes, and by increasing their capacity to engage directly in research and inquiry activities.

A perspective of collaboration

It is important to approach the integration of information technologies into social learning processes not as the simple application of proven methods or best practices to the solution of important social and educational problems, but rather from a perspective of collaboration. Technology is neither socially nor morally neutral. It contains possibilities for empowerment, but also for disempowerment, for example, through surveillance which reduces privacy and individual choice. The enthusiastic participation of all responsible parties is the key to defining and solving problems about learning and daily educational practices. Only in a constructive atmosphere can specific technologies be modified to address desirable goals related to academic skills, higher-order intellectual abilities, vocational skills, social understanding, citizenship participation, ethical development, and creative self-expression.

Equity

Inequalities of access to and use of information resources appear to be part and parcel of human circumstance whether in developing or in developed countries using or trying to use information technologies. The power to influence and control a work place, living space, or educational environment may be unequally distributed with respect to location, gender, age, race, ethnicity, handicapping condition, or social class. Realizing that power is a relative term, the group made the following recommendations in an attempt to foster more equitable access by learners to information technologies.

Recommendations

Recommendations for National Leaders

Acknowledge the need for improving education and for creating a climate favourable to the development of academic skills, higher-order intellectual abilities, vocational skills, social understanding, citizenship participation, ethical development, and creative self-expression. Encourage the integration of technology into the educational process in order that students may take advantage of its communication, visualization, modelling, and research potential. Ensure equity of access to and use of information resources. Invest in learning; invest in technology-rich learning.

Recommendations for Educators in Administration and Management

Work with parents, the community and the private sector to develop policy that will institute and sustain the use of information resources to support instructional processes. Support the continuing professional development of teachers. Promote instructional environments characterized by participation, flexibility and collegiality as a means of fostering new options for thought and action. Promote the integration of technology into the educational process.

Recommendations for Educators in Instruction and Human Development

Ensure that instruction is relevant and that it focuses on the important educational and developmental goals cited above. Use technology in daily educational practice in an integral rather than a peripheral manner.

Recommendations for Parents

Take responsibility for understanding the nature of schooling in your community. Work with school authorities to create policy that will improve education and support the important educational and developmental goals previously cited. Work towards equity of access to and use of information technologies. Invest in learning; invest in technology-rich learning.

Recommendations for Students

Accept responsibility for your own learning insofar as it is possible within your learning environment. Use educational technologies when they are available; request their use when they are not.

Recommendations for the Private Sector

Work with schools to create circumstances favourable to productive, efficient, humane, and inviting education environments. Encourage equity of access to and use of information technologies in the schools. Invest in learning; invest in technology-rich learning.

Focus Group Two: Relationships between Organization and Education

Questions for consideration

The following questions were considered by this Focus Group:

a) Flexible and open learning systems, including distance learning, offer major opportunities for expanding education and training provision. How dependant are these on the organization and funding of educational institutions?

b) How can old dogs learn new tricks? Are learners held back by teachers who are held back by administrators?

c) Introduction of computers changes organizations and working styles. How is education affected?

Method of Working

Sufficient participants elected for this set of questions to provide two sub-groups, one of which focused on the teacher as central to the debate about how curriculum is organised to deliver educational outcomes. The second sub-group looked at the wider policy environment in which schools and teachers have to operate. Both groups concluded that the support of policy makers at all levels was vital to enable learners to gain relevant and supported access to Information Technology in schools.

Focus Sub-Group A: Focus on the Teacher

Participants

The following persons participated in the work of Sub-Group A:

Bernard Dumont (Chair), Nora Levit Goldberg, Tom McMullan, Ferran Ruiz i Tarrago, François Samson, Ronnie Saunders, Deryn Watson (Rapporteur).

Discussion summary

The role of the teacher

The average teacher in the school is faced with a range of complexities in relation to using Information Technology. Teachers should not be considered part of a production line where the student is either the consumer or the product produced for society; this unhelpful analogy can lead to unfortunate statements and assumptions. Teachers and students are human beings who work together to prepare adults for life in society where their future employment is only one aspect of that life.

Special rewards for teachers?

Teachers do not have performance rewards like doctors and lawyers, and tend to be operating from within a system rather than offering their services to a system. Initial work on developing Information Technology in schools relied on enthusiastic volunteer innovators; only a minority of teachers are still involved; and the pioneers have moved on without leaving embedded use behind with colleagues. Should Information Technology teachers have special rewards?

Teacher support

Most teachers are still not as confident as pupils and think of computers as a "luxury", which can be problematic, time consuming and involves a variety of people such as technicians and network managers. Many use inappropriate pedagogical models; for example, resource based learning can be facilitated by informatics but still involves teachers.

Most teachers cannot adopt new practices alone without supportive structures which must include flexible organization, appropriate advice and technological support provided by non-teaching assistants. All teachers should have space and time to work with colleagues, contracts which reflect changed work practices and new definitions of their tasks for which they need extra time to integrate. Primary school teachers already have advantages of organization through absence of subject boundaries and class period times. These must inform secondary school practice.

The importance of the curriculum

The curriculum is a pivotal point in the relationship between organization and education whereas the teacher is the key to the delivery of the curriculum. Informatics in schools includes tools for teaching and learning, tools for management and organization, and is concerned with the technology itself; school informatics cannot totally mirror use in society yet the curriculum should try to reflect society's needs. Informatics must be curriculum driven and integrated into tertiary as well as secondary curriculum systems. It must also be seen to be important through incorporation within examinable aspects of the curriculum.

We need to look towards curriculum needs for year 2000; but change forecast as long as 15 years ago did not happen. It is possible that the conditions are now more favourable with the greater availability of hardware. Teachers recognize that new areas need to be introduced into the curriculum - the current focus is technology; they are given little clear guidance on what can be considered redundant to make way for the new. Subject boundaries are inhibitors; a cross curricular focus is probably the best way forward and reflects reality of society. Informatics is well placed to contribute to a cross-curricular focus in schools.

Funding

Organizing and resourcing special technological schools requires heavy funding which cannot usually be replicated; such projects do not necessarily have an impact on the rest. Bureaucrats, like teachers, may also be slow to take up informatics and are frightened of the implications of on-going financial commitment to changing technologies. As a result, schools will increasingly have to rely on local community and business support to supplement their own resources rather than major government projects.

Pupils

Pupils are often more confident with technology than teachers; they rapidly become clever users if there are enough facilities. But they increasingly feel current schools do not prepare them for real world of society and work. Pupils are influenced by home and society as much as the school; some pupils use informatics at home as well as at school, which highlights a real equity issue about the availability of informatics to pupils outside school hours who do not have their own equipment; this mirrors other similar problems, such as the availability of a quiet place to study.

Management support

Informatics needs to be used wherever possible to reduce and remove burdens from the teacher. Management systems can adopt informatics to: relieve teachers of some of their administrative tasks; put management control into the hands of teachers and local schools, so reducing time spent dealing with external bureaucrats; allow teachers and schools to analyse their organizational systems and so identify areas where they can be more efficient and give more time to teaching and related curriculum matters.

Recognizing that reorganization and change takes time and is an evolutionary not revolutionary process involving teams of people, the sub-group made the following recommendations to support teacher change.

Recommendations

National and regional policy

National and regional policies should be defined with clear aims and goals stated with respect to the role and use of informatics in schools, associated curriculum statements, guide-lines and requirements, which reflect the different cultural and social concerns of different societies.

Home and society influences on the use of informatics must be recognized and, where possible, appropriately utilized.

School policy

Whole school policies are essential which relate to national policies and integrated curriculum requirements and reflect the particular community of that school.

School organizational systems must change to support implementation of whole school informatics policies.

Educational organization

Flexibility should be encouraged through resource organization, location and access; time tabling and creating space for cross- curricular rather than rigidly subject based activities; creating physical space for teachers to work together in small teams to explore the implications and possibilities relating to use of informatics; allowing more time tabled time for teachers, separate from class time, for this exploration; reconsidering the physical space, layout and functions of buildings.

New people need to be introduced into the system, to provide functions which teachers should not need to fulfil, such as technical support. Also new and realistic contracts are required which recognize the changes involved.

Focus Sub-Group B: Focus on Policy Makers

Participants

The following persons participated in the work of Sub-Group B:

Doug Brown (Rapporteur), Lone Dirckinck-Holmfeld, John Gardner, Wolfgang Jansche, Immo Kerner, Raymond Morel (Chair), Goran Nydahl, Sten Odenwald, Ulf Vasstroem, Stanislaw Waligorski.

Discussion summary

Impacts of computers

The introduction of computers may affect educational organizations and teaching and learning styles in four possible ways:

- neither the organization nor teaching or learning styles change,
- the organization changes, but the working styles remain the same,
- the organization remains the same, but the working styles change, or
- both the organization and working styles change.

Preconditions for change

For the last of these to occur, all of the following need to come together and be fully supported:

- national and local school policies,
- organizational structure,
- teaching and learning methodologies curriculum development,
- teacher understanding and willingness,
- hardware and software support and access.

Support of policy makers at all levels is vital. Clearly learners can be held back by teachers held back by administrators. This can be because of lack of funding or because the policies do not support the necessary changes. There is a need for all those who have an influence on our education establishments to understand the nature and purposes of the changes enabled by the new technologies.

National programmes

Because we are talking about changes in education rather than simply changes in the use of new technologies, the greatest impact will be achieved if there is a national programme, or at least national co-ordination.

It is possible that, by use of statute, changes can be encouraged and development forced at a pace otherwise impossible. There have been examples, however, of national initiatives which have meant that students have been totally turned off the use of computers. If there is poor training, lack of preparation and little support, there is a real danger of such initiatives being counter- productive.

Possible cost benefits

The use of open and flexible learning styles may have cost benefits as well as other benefits. They may, for example, enable minority subjects to be delivered cost effectively in institutions and therefore enable a broadening of the curriculum available to learners. Such styles of learning will also enable the transfer to be made between secondary education and higher education more smoothly as students will be more used to controlling their own learning.

Evaluation

Since this style of learning challenges traditional perceptions, it also challenges traditional methods of evaluation. It is possible to give empirical examples of how teachers and others perceive worthwhile advances. Paired writing and the development of written language skills can be cited as examples, but the question of how we evaluate still remains unanswered if 'standards' of traditional criteria are to be maintained.

Policy makers need to address how we evaluate the effectiveness of this style of learning. If we are educating for a different future from that of our parents, are not the traditional criteria inappropriate for evaluation? Yet how do we then convince the agnostics and political representatives that this style of learning is more effective and should be encouraged?

Teacher training and retraining

The task of training and retraining teachers is already recognized as a massive one. We need to consider how best to target resources. It may be thought better to target new entrants to the profession. However, unless these new teachers are supported in their institutions, they can be overwhelmed by tradition, changes will not happen, and the investment will be wasted. It is possible that the teachers to target, though not exclusively, will be those who feel secure in the profession, but are still looking for ways to improve their effectiveness.

To ensure that any training is effective, it is necessary to understand the phase of development of any institution or area. It may be appropriate simply to train one person to act as a catalyst or co-ordinator, but it is well documented that the cascade form of spreading the use of technology and changes in learning styles is not effective and indeed, by itself, can be counter-productive.

It may appear more expensive, but for real institutional development to take place, it is probably necessary to train more than one person, possible three or four, and so ensure that support within the institution for change is ensured. In terms of long term effectiveness this may prove to be the least cost method.

It is also necessary to consider other forms of training than the traditional course which takes the teachers away from the school environment. Distance learning and school based activities can be an effective use of limited resources, but they do need central support. The paramount need is for organizational flexibility and continued support.

Educational organization

Open and flexible learning also need different structures to the traditional timetable. There needs to be flexibility in the school day and access to appropriate technology outside of the normal school hours.

The use of open learning and technological support systems will mean that some learning will be outside the teachers sphere of influence. There is therefore a concern that teachers may not be able to relinquish their traditional role and control. The teacher is no longer the fount of all knowledge - when the teachers are using the computer as a tool they may become joint participative learners. The teacher becomes a learning guide or a mentor for the students, co-operating with pupils in a learning experience.

These styles of learning are not new. Many have been tried in the past and were not successful because they presented a narrow predetermined curriculum unable to be adapted for the needs of individual learners. What is now different is the power that technology places in the hands of the learner enabling a broader curriculum and yet also a curriculum with greater depth accessible by all.

Challenges

This technological power means that the traditional curriculum is itself being challenged and changed with some traditionally taught material dropped as obsolete. In mathematics for example, once the basic skill of division is mastered it is no longer necessary to continue this to what is an unreasonable depth given that calculators are widely available.

The major challenge for policy makers is to ensure that teachers really understand the issues. It is very easy to say 'flexible and open learning' but far more difficult to put into practice. There will be a major problem if new teaching and learning styles are perceived as an additional skill to be learnt or additional work on top of the already overstretched and pressurized feelings that teachers share.

As Sub-Group A have stated, teacher training is perhaps the most important issue. In all our deliberations it is clear that the teacher is the key to success.

Focus Group Three: Educational Infrastructure

Questions for consideration

The following questions were considered by this Focus Group:

a) Can schools survive in a learner centred, technologically supported world?
b) What are the key requirements for effective learning in the next millennium?
c) Who should take responsibility for ensuring all citizens should attain their maximum potential?

Participants

The following persons participated in the work of the Focus Group:

Gary Bitter, Bernard Cornu (Chair), Chen Qi, Torben Bo Jansen, Stephen Marcus, Gail Marshall, Maria Rapallini, Richard Stockhammer, Harriet Taylor (Rapporteur), Paul Vachon, Jan Wibe

Discussion summary

An information rich environment

As Information Technology becomes more prevalent in a society, the key requirements for effective learning will include the development of attitudes, skills, and values that support and sustain productive life in an information rich environment. Traditional methods of education have required students to act as storers of information. Technological developments have led to an information explosion which mandates that students must now also become managers of information.

New goals for schools

To survive, schools and school systems are restructuring to meet new goals of education which aim to increase the general level of education for all students, to increase each student's ability to adapt to continuous change and to develop appropriate communication and interaction skills.

Change in educational infrastructure

Changing educational goals demand global change in the educational infrastructure. Systems once perceived as fixed and unchanging are no longer immune from rigorous scrutiny. All elements of educational infrastructure: the social, political, economic, cultural, and physical factors; all are candidates for change.

Traditional teaching methods which have fostered the passive reception of facts may be replaced by learner-centred experiences. Traditional classrooms which perpetuate teacher-domination could give way to open environments which promote co-operation between students and with students and teachers. Outdated learning theories which describe rote-processing of facts, will be re- evaluated in favour of cognitively-based theories which describe the dynamic nature of human behaviour.

This approach to educational infrastructure encompasses policies, practice, beliefs at all levels from national to local educational systems. Some elements of the educational infrastructure which are candidates for change include: policies, funding, teacher training, administrative practices, curricula development and implementation, facilities procurement and management, media, and organizational practices.

Policies

Future policies to support technology rich learning should include the following features: new links and networks between practitioners and policy makers; funding for technology as a continuous operation; re-examination of resource allocation; and technical support to enhance and maintain the new infrastructure.

Characteristics of a new infrastructure

For true change to occur, a restructuring of the system rather than a simple introduction of technology into the present system is necessary. Often, when technology is introduced, the result is a simple automation of existing teaching practices and methods which does not advance the society. Schools that evolve using a planned information oriented approach will have characteristics as follows.

Learner-orientation

Educational systems will support the development of individual students allowing for individual autonomy and decision making. This includes new roles for teachers as collaborators, facilitators, resource managers, and leaders with appropriate changes in teacher training and development of methodologies that support the learner orientation model.

Technology support

Educational systems will have as a basic requirement adequate hardware, software, and technical support. New trends in technology, such as the current advances in telecommunications, networking, databases, and multimedia, will be incorporated in the system.

Integrative curricula

Curricula will be developed in the context of the new school style. These curricula will concentrate on an integration of learning and will be developed through a reconceptualization of the linkage across subjects and a fostering of the interrelationships between subjects. Materials, methods, and assessment techniques that promote the new learner orientation and reflect the support of technology as a standard will form the core of the instructional process

Restructured organization

For true co-operation to exist, schools will move in the direction of a change of scale towards smaller, community-like models. Open, learner-centred education replaces the traditional closed class-based model. Co-operation between schools, teachers, and the entire community is an integral part of the structure.

Adapted school settings

School settings including facilities, personnel structure, media and resource management, funding procedures, policy mechanisms, and objectives will evolve as part of the restructured infrastructure.

Conclusions

Educational systems thrive only when all members of the community are partners in the process. Previous attempts to change have been limited to pilot projects which have targeted special groups but have failed to accommodate the system as a whole. The challenge posed by Information Technology is a once in a century phenomenon similar to the challenge posed by the transition from an agrarian culture to an industrial society. A new technology-based, learner-oriented educational infrastructure is necessary for schools to survive in the next millennium.

Focus Group Four: Economics of Education

Questions for consideration

The following questions were considered by this Focus Group:

a) Can control and direct supply of resources for schooling by government be as effective as funding through subsidy for individuals?

b) How is the cost of learning measured?

c) How is the cost of effective learning measured?

Participants

The following persons participated in the work of the Focus Group:

Ludwig Braun, Betty Collis, Monique Grandbastien, Jef Moonen, Erich Neuwirth (Chair), Paul Nicholson (Rapporteur).

Discussion summary

Decision making

Decision making concerning technology in education is going on all the time, at every level. For example, the classroom teacher decides if he should make use of the technology available in his school in his lessons for the day. The principal considers buying an administrative software package to co-ordinate student records and results. Ministry staff consider a system-wide plan for teacher training about the use of new media in the classroom. In these and countless other decisions, ranging from on-the-spot and informal to wide-reaching and carefully studied, a basic thinking process is going on. Will the efforts be worth it?

Policy

As with Focus Group Three this group considered key policy questions. Can we expect to get a good return for what it will cost us? Considering what it may cost us, are the benefits going to be important enough for us to go ahead? We can think of this as a "payoff" versus "expenditure" thinking process. What can strengthen it?

In each case, decision making is, at a global level, a comparison of expected or hoped-for benefits balanced against predicted costs and then considered in the context of overall resources and priorities. Often however, decision making occurs with incomplete information. The articulation of benefits from the use of technology requires a distinction between short and long term outcomes, and a separation of the effects of using technology from the wider school context.

Potential benefits of technology

Some of the potential benefits of using technology, which can occur at different levels, are listed as follows.

Students

Students develop higher order thinking skills, adjust to different learning styles, gain access to information - and modes of processing that information, which are not possible without the use of technology - and are more motivated by learning, even those who are not currently interested in school.

Teachers

Teachers have reduced administrative workloads so that they can spend more time with their students, and teaching becomes more exciting.

Administrators

Administrators achieve better decisions in resource allocation, better management of resources, and better assessment.

Parents

Parents realise greater aspirations for their children.

Society

Society gains a better prepared workforce.

Many of these perceived benefits have been observed without being quantified. We need to develop ways of measuring these intangible outcomes, and of deciding on the nature of evidence that can be used in this process. We need better indicators to show how the use of technology matches the learning processes so valued by classroom practitioners.

Analysis of cost

The following list of costs is intended to be indicative of the nature and range of issues to be considered in a careful cost analysis relating to technology. It is particularly important to include the items we have listed under the category of "hidden costs", as these are frequently overlooked in many decision making processes.

Infrastructure costs

Infrastructure costs include hardware, software, curriculum design, and facilities reorganization.

Operational costs

Operational costs include maintenance, teacher training - both short and long term, support services, equipment replacement and upgrades, insurance, and technical support.

Hidden costs

Hidden costs include intellectual energy in learning new technology, psychological effort in adjusting to change, displacement costs, and technological support services external to the school.

Expected payoff

Good decision making is based on knowledge of as many influential variables as possible. Careful thought should be given to identifying the benefits expected from using technology within the overall priorities of your system before making, or arguing about, a particular decision.

Key questions are:

- Is the expected payoff sufficiently important to the system to justify the costs?
- When will costs become too high, regardless of the hoped-for benefit? - Can costs be reduced, if the benefit is important enough? Or:
- Can you convince the decision maker that the benefits may indeed become "important enough" to justify sustaining the costs, at least up to the "too expensive" level?

Different people will weigh cost and benefit components differently, but there should be some consensus about the main cost and benefit factors. There is, however, no easy path to accurate decision making in this area, because the nature and range of costs and benefits is so multi-dimensional.

Bibliography

[Aike80] Robert M. Aiken and Ludwig Braun, "Into the 80's with microcomputer-based learning", IEEE, July 1980.

[Aike89] Robert M. Aiken, "Great Expectations", in [WG3.189].

[Aike92] Robert M. Aiken (ed.), "Education and Society - Information Processing 92", IFIP Transactions A-13, proceedings of the IFIP 12th World Computer Congress, Madrid, September 1992, North-Holland, 1992.

[Baro89] Georges-Louis Baron, "Computers in education: the shape of things to come". UNESCO, Bulletin of the International Bureau of Education, N. 260; January-March 1989.

[Beav90] J.F. Beaver, "Sharing the vision, power and experience: increasing the computing competence of our administrators", proceedings of "The Seventh International Conference on Technology and Education", Brussels. CEP Consultants Ltd., March 1990.

[Beck91] Henry Jay Becker, "How computers are used in United States Schools: Basic data from the 1989 I.E.A. computers in education survey", J. Educational Computing Research, Vol 7(4), 385-406, 1991.

[Bish84] Peter Bishop, "The response of secondary education to the Alvey Report", in E. Ramsden (ed.) "Microcomputers in Education 2", Ellis Horwood, 1984.

[Boll88] Peter Bollerslev, "Information Technology in Teacher Education", IBM Danmark A/S, 1988.

[Boll90] Peter Bollerslev, "Evaluation of The Nordic Committee on Educational Software and Technology - Activities and Results until 1990", Nordic Council of Ministers, 1990.

[Bork89] Alfred Bork, "The History of Computers and Education" (draft paper). Educational Technology Center, University of California, Irvine, Feb 17, 1989.

[Bran90] Walter Branch, "Trojan and Viral Programs: Implications for Classroom Computing", Computers in the Schools, Vol. 7, No. 3, 1990.

[Brow90] A.J. Brown, "Support for and management of IT in schools", proceedings of "The Seventh International Conference on Technology and Education", Brussels. CEP Consultants Ltd., March 1990.

[Brui87] Magda Bruin, "A case study of an in-service teacher training in The Netherlands: Primary school teachers learn to integrate existing software in the curriculum", proceedings of the EEC Seminar "Implications of NIT in teacher training", Madrid, 25-28 November 1987.

[Brui92] Magda Bruin, "A Century After Lady Lovelace's Tragedy", in [Aike92].

[Call87] D. Callison, "Evaluator and Educator: The School Media Specialist", TechTrends, October 1987.

[Cart87] Carolyn Carter & Jenny Monaco, "Learning information technology skills", Library and Information Research Report 54, The British Library, 1987.

[CCW90] Curriculum Council for Wales, "Information Technology in the National Curriculum - Non-Statutory Guidance for Teachers", Cardiff, 1990.

[Cerr92] S.A. Cerri & J. Whiting (eds.), "Learning Technology in the European Communities", Proceedings of the DELTA Conference on Research and Development, The Hague 18-19 October 1990. Kluwer Academic Press, 1992.

[CinE90] "DVI Technology From Intel", Computers in Education, April 1990.

[CinE91] "The 1991 Computers in Education Survey of Microcomputers", Computers in Education, Mar/Apr 1991.

[COM89] European Economic Community COM(89) 236, 1989.

[Croo91] Charles Crook, "Computers in the zone of proximal development: implications for evaluation", Computers & Education, Vol. 17, No. 1, 1991.

[Cumm90] Jim Cummins and Dennis Sayers, "Education 2001: Learning Networks and Educational Reform", The Haworth Press, Inc., 1990.

[C&E91] "Understanding the Learning Process", monographic issue of Computers & Education, Vol. 17, No. 1, 1991.

[Davi75] W.J.K. Davies, "Learning resources - an argument for schools", Council for Educational Technology, London, 1975.

[Davi89] L. Davie, "Facilitation Techniques for the On-line Tutor", in [Maso89].

[DENI89] "Information Technology: A Cross Curricular Theme", Department of Education of Northern Ireland, 1989.

[DES89] Department of Education and Science, "Information technology from 5 to 16", Curriculum Matters 15, HMI Series, HMSO Publications Centre, London, 1989.

[DES91] Department of Education and Science, "Statistical Bulletin", Government Statistical Service (UK), June 1991.

[Drag88] Chris Drage & Nick Evans, "Teacher Friendly - A Guide to Using Micro's in the Classroom", Learning Development Aids, Wisbech, Cambs. 1988.

[Dudl90] G.A. Dudley & W.O. Dudley, "Using lap computers to integrate computers into a variety of curricular areas", in the proceedings of "The Seventh International Conference on Technology and Education", Brussels, March. CEP Consultants Ltd. 1990.

[Dunk88] M.J. Dunkin, "Technical Skills of Teaching", International Encyclopedia of Education", Pergamon Orbit InfoLine Ltd., London, 1988.

[Durn91] A. Durndell, "The persistence of the gender gap in computing", Computers & Education, Vol. 16, No. 4, 1991.

[ECOJ83] European Communities Official Journal, N.C 256, 24-9-83.

[Erik91] I.V. Eriksson, B.A. Kitchenham and K.G. Tijdens (eds.), "Women, Work and Computerization: Understanding and Overcoming Bias in Work and Education". Proceedings of the IFIP TC9 / WG9.1 Conference on Women, Work and Computerization, North-Holland, 1991.

[ETAS91] Educational Technology Anthology Series, Volume Three, "Telecommunications for Learning", Educational Technology Publications, Englewood Cliffs, New Jersey, 1991.

[Ewar89] R.W. Ewart, "Campus Network Perspective", proceedings of "Dynamics & Visions", IBM Seminar, La Hulpe, Belgium, March 8-10, 1989.

[Fein89] B. Feinstein & B. Kurshan (eds.), "Proceedings of the I nternational Symposium on Telecommunications in Education: Learners and the Global Village", Jerusalem, August 1989, edited by ISTE, Oregon, 1989.

[Fiel78] J. Fielden & P.K. Pearson, "The Cost of Learning with Computers", Council for Educational Technology, 1978.

[Foth88] Richard Fothergill, "Implications of New Technology for the School Curriculum", Kogan Page, 1988.

[Garc90] Luís A. García-Ramos, "Hardware para la enseñanza. Perspectivas" (Hardware for teaching. Perspectives), I Jornades d'informàtica aplicada a l'escola. Girona, Spain, September 3-7 1990.

[Gore89] Kay Gore, "If You Meet the Computer Guru on the Road, Kill Him (or Her)", Computers in the Schools, Vol. 6, Nos. 3/4, 1989.

[Gran91] Monique Grandbastien, "Conditions for an Effective Integration of Educational Technologies in Secondary Schools", in [WG3.191].

[Gray89] R. Gray, "CMC for in-service training", in [Maso89].

[Gwyn86] Rhys Gwyn, "Towards a pedagogy of information", in "Information Technology and Education - The Changing School", edited by R. Ennals, R. Gwyn and L. Zdravchev, Ellis Horwood Limited, 1986.

[Hall86] Noelle Hall, "Teachers, information and school libraries", Paris, UNESCO, 1986.

[Haug89] Harald Haugen, "Development Tools for Educational Software: Open-Ended Software and Creative Programming Tools", in [WG3.189].

[Hebe89] Jacques Hebenstreit, "Megatrends in Educational Software", in [WG3.189].

[Hebe92] Jacques Hebenstreit, "Computers in Education - The Next Ten Years", Opening speech of the International Conference on Technology in Education, Paris, 16-19 March 1992.

[Hell91] Rachelle S. Heller, "Evaluating software: a review of the options", Computers & Education, volume 17, number 4, 1991.

[Hunt89] Beverly Hunter, "Designing Educational Software for the Information Age: Dilemmas and Paradoxes", in [WG3.189].

[Hunt90] W.L.R. Hunter & D.H. Maddocks, "Information Technology - A Curriculum Map", Hunter Press, Durham, 1990.

[IFIP71] IFIP Working Group on Secondary Education (WG 3.1), Computer Education for Teachers in Secondary Schools An Outline Guide, IFIP, Sept. 1971.

[IFIP72] IFIP Working Group on Secondary Education (WG 3.1), Computer Education for Teachers in Secondary Schools Aims and Objectives in Teacher Training, IFIP, Oct. 1972.

[IFIP75] IFIP Working Group on Secondary Education (WG 3.1), Elements of Information and Information Processing for Teachers in Secondary Schools, IFIP, 1975.

[Irvi85] Ann Irving, "Study and Information Skills across the Curriculum", Heinemann Educational Books, London, 1985.

[Irvi91] Ann Irving, "The educational value and use of online information services in schools", Computers & Education, Vol. 17, No. 3, 1991.

[ISTE90] International Society for Technology in Education, "Vision TEST - Executive Summary of the Final Report", supplement to The Computing Teacher, 1990.

[Jens89] Poul Erik Jensen & Lars Kleve, "Gender differences and computer use in education", Danish Institute for Educational Research, Copenhagen, 1989.

[Kang91] Le Kang et al., "Complete university timetable using logic", Computers & Education, Vol. 17, No. 2, 1991.

[Kirb90] Peggy C. Kirby et al., "Computers in schools - a new source of inequity", Computers & Education, Vol. 14, No. 6, 1990.

[Kris89] Anna Kristjánsdóttir, "Educational Software - On Whose Terms?", in [WG3.189].

[LaBo91] René La Borderie, "The Contribution of Videotext to the Management and Use of Learning Resource Centres", Educational Media International, Vol. 28, No. 4, December 1991.

[LaMo90] D. LaMont Johnson, "Editorial", Computers in the Schools, Vol. 7, No. 4, 1990.

[Lang82] Fred E. Langhorst, "Working towards standards in graphics", Computer Design, July 1982.

[Legr90] M.C. Legrotagglie et al., "Implementation Considerations about Cooperative Learning in On-line Education", EC Newsletter, Vol. 2, No. 3, Sep - Dec 1990.

[Lick84] J.C.R. Licklider, "Information Technology, Education, and the American Future", in Dale Peterson (ed.) "Intelligent Schoolhouse - Readings on Computers & Learning", Reston Publishing Company, Inc. 1984.

[Lin91] Herb Lin, on EDTECH computer conference "Computers into schools - working the numbers", <HLIN@AS.BITNET>, 16 Aug 1991.

[Love91] G. Lovegrove & B. Segal (eds.), "Women into Computing: Selected Papers 1988-1990", Springer-Verlag, 1991.

[Lovi88] F. Lovis & E.D. Tagg (eds.), "Computers in Education", proceedings of IFIP European Conference on Computers in Education ECCE 88, North-Holland, 1988.

[Macl91] Stuart Maclure & Peter Davies, "Learning to Think - Thinking to Learn", proceeding of the 1989 OECD/CERI Conference, Pergamon Press, 1991.

[Mark91] Gerald Marker & Lee Ehman, "Linking Teachers to the World of Technology", in [ETAS91].

[Makr92] V. Makrakis, "Cross-Cultural Gender Differences in Student Self-Efficacy: The Impact of Culture", in [Aike92].

[Marl81] M. Marland (ed), "Information skills in the secondary curriculum", Schools Council Curriculum Bulletin 9, Methuen Educational, London, 1981.

[Mart87] Peter H. Martorella & Ellen S. Vasu, "Developing a New Generation of Technology Leaders", Educational Technology, November 1987.

[Mart91] C. Dianne Martin, "New findings from qualitatively data using hypermedia: microcomputers, control and equity", Computers & Education, Vol. 16, No. 3, 1991.

[Mart92] C.D. Martin, "Addressing the Gender Gap in Informatics Education", in [Aike92].

[Maso89] R. Mason & A. Kaye (eds.), "Mindweave - Communication, Computers and Distance Education", Pergamon Press, 1989.

[Masu80] Yoneji Masuda, "The Information Society as Post-Industrial Society", 1980.

[McAn90] Thomas R. McAnge, Jr., "A Survey of Educational Computer Networks", <LISTSERV@UNMVM.BITNET>, June 1990.

[McDo90] A. McDougall and C. Dowling (eds.), "Computers in Education", proceedings of the IFIP TC3 Fifth World Conference on Computers in Education (WCCE 90), Sydney, Australia, July 1990, North-Holland, 1990.

[McLe88] Robert S. McLean, "Local Area Networks in Education: An Infrastructure Perspective", in Computers in Education, F. Lovis and E.D. Tagg (eds.). Elsevier Science Publishers, IFIP, 1988.

[McLe89] Robert S. McLean, "Megatrends in Computing and Educational Software Development", in [WG3.189].

[McMu91] Tom McMullan, "Administrative Informatics in Schools; the Northern Ireland CLASS Project", in [WG3.191].

[Moon89] Jef Moonen, "Courseware Development at the Crossroads?", in [WG3.189].

[Moon91] Jef Moonen & Betty Collis, "Changing the School: Experiences from a Dutch 'Technology-Enriched School' Project", in [WG3.191].

[Mour91] Dave Moursund, "Restructuring Education Part 3: What is the Information Age?", The Computing Teacher, November 1991.

[Nais82] J. Naisbitt, "Megatrends: Ten New Directions Transforming Our Lives", New York, Warner Books, 1982.

[Niev80] Jurg Nievergelt, "A Pragmatic Introduction to Courseware Design", IEEE, September 1980.

[Norm87] Jeremy Norman, "Information Skills and Information Technology - Case Studies and Training Material", Council for Educational Technology, 1987.

[Nyda88] Göran Nydahl, "Experts Systems in Education", IBM Seminar, La Hulpe, Belgium, May 30 - June 1, 1988.

[OECD86] "New Information Technologies - A Challenge for Education", OECD, 1986.

[OECD87] "Technologies de l'information et apprentissages de base", OECD, 1987.

[OECD88] "New Technologies in the 1990s - A Socio-economic Strategy", OECD, 1988.

[OECD89] "Les technologies de l'information et l'éducation - Choisir les bons logiciels", OECD-CERI, 1989.

[OShe83] Tim O'Shea & John Self, "Learning and Teaching with Computers - Artificial Intelligence in Education", The Harvester Press, 1983.

[OTA88] Office of Technology Assessment, "Power On! New Tools for Teaching and Learning", Congress of the United States, Washinton, U.S. Government Printing Office, 1988.

[OTA89] Office of Technology Assessment, "Linking for Learning - A New Course for Education", Congress of the United States, Washinton, U.S. Government Printing Office, 1989.

[Pelg91] Willem J. Pelgrum & Tjeerd Plomp, "The Use of Computers in Education Worldwide". Results from the IEA "Computers in Education" Survey in 19 Education Systems, Pergamon Press, 1991.

[Plom91] Tjeerd Plomp and Willem J. Pelgrum, "Introduction of computers in education: state of the art in eight countries", Computers & Education, Vol. 17, No. 3, 1991.

[Quar90] John S. Quarterman, "The Matrix - Computer Networks and Conferencing Systems Worldwide", Digital Press, 1990.

[Ray91] Doris Ray, "Technology and Restructuring - Part II: New Organizational Directions", The Computing Teacher, April 1991.

[Rica91] Ricardo Marques, Maria Emilia, "Developing School Media Libraries for the Autonomy of Linguistic Minorities", Educational Media International, Vol. 28, No. 3, September 1991.

[Riel89] Margaret Riel, "Four Models of Educational Telecommunications; Connections to the Future", Education & Computing 5, 1989.

[Ruiz92] F. Ruiz Tarragó, J. Vivancos, & J. Baldrich, "XTEC Online In- Service Teacher Training Project", in [Cerr92].

[Rush92] N. Rushby, "Perpetuating the Myth", in [Cerr92].

[Ryba90] Ken Ryba et al., "Learning with Computers: Effective Teaching Strategies", ISTE Publications, 1990.

[Sams91] Francois Samson, "The Microcomputer as an educational Aid for developing the Pupils' Autonomy: An Experiment Carried out at the Lycée Pilote Innovant", in [WG3.191].

[SED87] Scottish Education Department, "Learning and Teaching in Scottish Secondary Schools: the Use of Microcomputers", a Report by HM Inspectors of Schools, Edinburgh, 1987.

[Shim92] Yasukata Shimizu, "Computer Use in Japan's Schools", Educational Technology, March 1992.

[Simo92] Cristina Simón, "Telematic Support for In-Service Teacher Training", in "Collaborative Learning Through Computer Conferencing", edited by A.R. Kaye. NATO ASI Series, Springer-Verlag, 1991.

[Steb90] Barry Stebbins, "HyperCard: The Tool for the Classrooms of Tomorrow", Computers in the Schools, Vol. 7, No. 4, 1990.

[Stef90] Douglas Stefanko et al, "Education Technology - A Corporate Weapon in the 1990s Marketplace", Unysis Corporation, Princeton, New Jersey, 1990.

[Stre86] Michael J. Streibel, "A Critical Analysis of the Use of Computers in Education", ECJT, Vol. 34, No. 3, 1986.

[Swin90] John Swinimer, "The 1989 Computers in Education Survey", Computers in Education, April 1990.

[Tayl80] R. Taylor (ed.) "The Computer in the School: Tutor, Tool, Tutee".New York, Teachers College Press, 1980.

[Tayl91] Harriet G. Taylor, Robert M. Aiken, Tom J. van Weert, "Informatics Education in Secondary Schools", IFIP Working Group 3.1 Guidelines for Good Practice, 1991.

[Tele90] Moshe Telem, "MIS possible impact on educational organizations as loosely-coupled systems", Computers & Education, Vol. 14, No. 6, 1990.

[TTEC91] Proceedings of the "Technology and Teacher Education Conference", Grenville, North Carolina, May 10-12 1990, Computers in the Schools, Vol. 8, Numbers 1/2/3, 1991.

[Turn73] C. Turney, J.C. Clift, M.J. Dunkin & R.D. Traill, "Microteaching: Research, Theory and Practice", Sydney University Press, Sydney, 1973.

[Turn91] Graham Turnbull & Tom Gilmour, "Laptops in the Scottish Primary School: Interim Report", Educational Media International, Vol. 28, No. 2, June 1991.

[UNES82] UNESCO, "L'informatique - facteur vital du développement", 1982.

[UNES85] UNESCO, "Programme modulaire pour l'enseignement de l'informatique", 1985.

[UNES89a] UNESCO, "Nouvelles technologies de l'information en éducation. Declaration de congres 'Éducation et informatique'", Paris, EPI, núm. 55, 1989.

[UNES89b] UNESCO, "Education and Informatics. Strengthening International Co-operation", proceedings of the UNESCO International Congress, Paris, April 12-21, 1989.

[UNES91] UNESCO, "A European Platform to Develop a Mechanism for Co-operation in the Field of Information Technologies in Education", Final report and proceedings. Seminar held in Moscou, 17-21 June 1991.

[Upit90] Rena Upitis, "Real and contrived uses of electronic mail in elementary schools", Computers & Education, Vol. 15, No. 1-3, 1990.

[Vass91] Ulf Vasström, "Nordic Committee on Educational Software and Technology - Activities and Results until 1991", Nordic Council of Ministers, 1991.

[Veen92] Wim Veen & Fred Vogelzang, "Telematics in Dutch Education - Experiences from the Classroom", IVLOS Institute of Education, Utrecht University, 1992.

[Verg92] Martí Vergés, "Developments in Information Technology and Media, and the Maintenance of Language and Culture in Small Linguistic Societies", Educational Media International, Vol. 29, No. 1, March 1992.

[Wats90] Deryn M. Watson, "The classroom vs the computer room", Computers & Education, Vol. 15, No. 1-3, 1990.

[Wats91] Deryn M. Watson, "Computer classes or curriculum integration?", short paper presented at IFIP WG 3.1 Working Conference "The Impacts of Informatics on the Organization of Education", Santa Barbara, California, August 1991, [WG3.191]

[Weer91] Tom J. van Weert, "Informatics and the Organization of Education", in [WG3.191].

[WG3.189] Proceedings of the IFIP WG 3.1 Working Conference "Educational Software at Secondary Level", Reykjavik, June 1989, Elsevier Scientific Publishers.

[WG3.191] Proceedings of the IFIP WG 3.1 Working Conference "The Impacts of Informatics on the Organization of Education", Santa Barbara, California, August 1991, Elsevier Scientific Publishers.

[Whit88] John Whiting, "New perspectives on open and distance learning for adult audiences", in "World Yearbook of Education 1988 - Education for the New Technologies", edited by Duncan Harris. KoganPage, 1988.

[Whit89] Mary-Alice White, "Current Trends in Education and Technology as Signs to the Future", in [WG3.189].

[Wild91] P. Wild, "The effectiveness of INSET in CAL and IT: an evaluation of the work of an advisory teacher", Computers & Education, Vol. 16, No. 4, 1991.

[Will88] S. Wills & R. Lewis (eds.) "Micros plus: educational peripherals", proceedings of IFIP 88. North-Holland, 1988.