SCHOOLNET / RESCOL

THE CONTRIBUTION OF NEW TECHNOLOGIES TO LEARNING AND TEACHING IN ELEMENTARY AND SECONDARY SCHOOLS

DOCUMENTARY REVIEW

Français

A collaboration of Laval University and McGill University

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Acknowledgments

By its very nature, this review is the product of a collaborative search between practitioners, policy makers and researchers to ground on firm research results the decisions that pertain to the integration in the classroom of information and communication technologies. We are grateful here to the SchoolNet Advisory Board (SNAB) and its Training, Research and Evaluation Sub-Committee, which initiated, in November 1995, under the leadership of Edward T. Wall, Dean of Education at McGill, the process of building a shared vision of the Learner in the 21st Century.

This project pointed to the necessity of reviewing the literature in orde to identify the potentials of information- and communication-rich learning environments for school learners and teachers. The reviewers have benefited from the support of Industry Canada (SchoolNet) that provided the necessary funding for the preparation and publication of this first edition of the review. In particular, we want to signal Doug Hull's perceptive and operative mind, and the dedication of the members of the team, led by Elise Boisjoly, that carries the SchoolNet mandate.

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We owe a great debt to Réginald Grégoire inc., a highly regarded consultant firm specialized in documentary reviews intended for policy makers in Quebec's field of education. The integrity of the French version they submitted on June 28th 1996 was outstanding. We also thank Debra Michael and Marcos Silva for their help in searching for and obtaining relevant documentation.

Aiming at informing the educational conversation on a subject that changes at an accelerated pace, the electronic publication of this review is bound to be modified on a regular basis. The August 1st version (both in English and in French) differs substantially from the June 15th draft that was received by the SNAB. The results of new concrete experiences and the emerging socio-technic models will progressively be included. As suggested by Marita Moll, from the Canadian Teachers' Federation, a related document that focuses on contexts in which new technologies are being integrated, that is, the culture of the school and of the classroom, must be developed. We hope that this documentary review will draw potential partners into a collaborative electronic space for further discussion, one that will lead to an enriched and more refined knowledge-base, and one we collectively share. Thanks.

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INTRODUCTION

Defining the Subject Matter

What are widely called New Information and Communication Technologies (NICT) are currently arousing curiosity in many elementary and teaching environments. Now aware of the growing role that these technologies occupy in numerous spheres of social life and the attraction they hold, in many forms, for young people, we wonder about the attention that the school system should give to them, and specifically what contribution they could make to student learning and to instructional practice.

The expression "new information and communication technologies" (which in the remainder of this report we will shorten to "new technologies") refers here to a series of technologies that usually include the computer and which, when combined or interconnected, are characterized by their power to memorize, process or make accessible (on a screen or other support) and to transmit, in principle to any place at all, a virtually unlimited and extremely diversified quantity of data. In addition, it is worth pointing out that these new technologies are found with increasing frequency in various forms: text, diagram, graphs, moving images, sound, etc.

Since these technologies are by definition new, it is not possible to take stock of their "contribution" in the same way as we would an existing education technology. In the vast majority of cases, the applications of these technologies that we find in the school system are part of pilot projects or experiments whose environment, most often, is only partially in harmony with their characteristics and possibilities. It is for this reason that this documentary review cites only recent documents (i.e., published since 1990) and, moreover, is interested not only in hard scientific conclusions, but also research findings, which, although still tentative, are conducive to stimulating current thinking on teaching and learning models and the reform of the school system. It is worth noting that this latter approach is justified by the fact that if we refer to the existing body of knowledge on relations between technology and education "it is becoming increasingly clear that technology in and of itself, does not directly change teaching or learning. Rather, the critical element is how technology is incorporated into instruction." (US Congress, Office of Technology Assessment, 1995, p. 57. In the same vein, see also O'Neil, 1995, p.6, and Guthrie and Richardson, 1995, p.17).

The perspective taken by educational researchers and practitioners concerning the role of computer-based learning technologies in the classroom has shifted significantly in the past decade. The perspective of the early 1980's can be characterized as 'the computer as an agent of change' (see Mehan, 1989). That is, the technology was expected to have a major and direct impact on student learning and skill acquisition. This was particularly the case for the subject areas of writing (where word-processing software was immediately available) and of mathematics (where various computer-based Logo software was widely available) (see for example, Daiute, 1983; Rubin and Bruce, 1985).

The at-best mixed results that were obtained for the effects of the technology on learning reduced expectations for the technology (see Hawisher, 1989), and led to a perspective that can be characterized as 'the computer as a tool'. That is, the technology can be an important component of bring about new and better kinds of learning; but as with all tools, effective use of the technology is embedded within practices and activities that realize its functionality for specific purposes and situations. The investigation of the relationship between practices, purposes, and situations and computer-based learning technologies has been the general driving force motivating the recent research reviewed below.

The learning at issue is that provided for elementary and secondary students within their tangible experiences in which new technologies are used. Thus, it usually The student learning that is examined in light of the new technologies refers to languages, math, the humanities, natural sciences, the arts and, at the end of secondary school, to certain professional content, as well as intellectual skills that are associated with these various subjects: ability to give oneself a mental image of reality, to reason, to make judgments, to solve various types of problems, to invent, etc. This learning is also, for example, the development of personal independence and responsibility, as well as various social skills and conduct, including and first within the educational facility itself. Under these circumstances, attention is not focused solely on learning as an internal process of the individual. There are also the traditional phases of preparation, communication and assessment in teaching, student support activities and the environment established to stimulate a process of discovery and assimilation by the students.

Selecting the Documents

This documentary review focuses on relationships between the new technologies and student learning at the elementary and secondary levels. To be more specific, its objective is to shed light on the way in which these new technologies come into play in the learning process itself and on the immediate environment which is usually introduced in a school or a classroom to ensure this learning, as well as the impact these actions have on the students.

Within this field, a selection was made from two categories of documents, which we agreed to call "assessments" and " essays." For the purpose of this study, these categories of documents were defined in the following way:

- **Systematic assessment** : any text that gives an account of the assessment of an experiment, regardless of the scope of the experiment that gave rise to the assessment at issue. These assessments preferably will have been conducted by an independent external body or under its supervision, but we will not necessarily reject assessments made by those responsible for the experiments assessed, if it is evident that they collected the information methodically and conducted a scientific analysis.

- **Essay** : any document published in a book, periodical, conference or symposium proceedings or elsewhere that proposes or studies in depth a concept or framework of reference with the objective of pinpointing or characterizing the contribution of new technologies to student learning or highlighting their possibilities. Such trials may grow from specific experiments or may take place within broader thinking (for example, focusing on the reform of the school system or on relations between teaching staff and technology).

This selection was made in two stages. During the first stage, an initial general selection grid was established and, in relation to each of the subthemes considered, working hypothesis were developed. The second stage, covered by this report, consisted of testing each hypothesis by carefully analyzing the specific documents, including a number of new ones. The initial hypothesis, revised and corrected, then became ***observations.*** Given the time and resources available, we had to limit the number of documents studied. All were published in North America, but some of them referred to situations in Europe and Oceania. It would be interesting to conduct a similar study on francophone documents, published in Quebec or elsewhere.

Each observation-14 in all-is supported by a summary of the experiment or trial assessments or, in some cases, studies belonging to each of these categories. The content of these "reference points" (which is in fact the title given to these summaries) basically consists of two types of information: one type focuses on ***the context*** of the document in question: origin, justification, level of education, scope of the experiment assessed, etc.; the other type focuses on ***the findings*** of the assessment or ***the thrusts*** that the essay considers. However, when a document supports more than one observation, the context is only described at the first reference; subsequently, with the odd exception, we simply refer to the first reference.

Most of the research that is reviewed comes from studies that included either a) a separate control group of students against which results obtained from an experimental treatment group can be compared, or b) pretest measures of results from the experimental group against which post-test measures can be compared. For a number of studies, both types of measures are available. An additional criterion for inclusion of a study concerned the reporting of methodology: Those studies selected for review are ones in which the methodology is reported in sufficient detail that it would be possible to replicate the research.

In all cases, the thrusts and findings reported are limited to what was considered relevant to the observation formulated. Most of these documents contain other points on other aspects of technology in education that are worthy of interest. It should also be noted that a high proportion of the documents considered were openly based on the others, which were older, including, quite often, studies or reviews of documentation deemed classics on the subject.
We prepared this report focusing on the use that could be made of these summaries by people called on to make decisions regarding the use of new technologies in education, as well as the anchor points and work avenues that could be found by teachers already aware of the opportunities offered by new technologies.

Outline of the Report

This report is structured around two research axes deemed the most suitable for covering the field of the envisaged documentary review:

- **The contribution of new technologies to student learning** and
- **The consequences of appropriate use of new technologies on the teaching function of teachers.**

Within each of these axes, the observations are, in each case, grouped around three **themes:**

in relation to the first axis,

- the specific learning achieved,
- student motivation,
- and the relationship of students to knowledge,

and, in relation to the second,

- planning teaching,
- intervention with a group of students,
- and the assessment of learning.

Each theme in turn includes as many subthemes as there are observations. The table of contents allows the reader to see at a glance the subthemes discussed, as well as the theme and the research axis to which each one of them is linked. In addition, each division or subdivision of the report contains a short introduction. All the observations are presented in the same way, in three parts: reference to the subtheme on which the observation is focusing, the observation statement and several reference points.

I. THE CONTRIBUTION OF NEW TECHNOLOGIES TO LEARNING

Introduction

In this first part, this documentary review focuses on three themes, which have a direct and immediate relationship with the contribution made by new technologies to student learning: the specific learning that students achieve, motivation of students who use the technologies for learning, and student relationship to learning. On each of these themes, viewed from the perspective of the influence that new technologies exert on them, there exists a considerable number of trials and assessments. Since this report can only be the first step in a broader, long-term project, only some of these studies have been considered here. However, since all are recent, they are a summary and extension of many others. Moreover, we feel they demonstrate that the potential of new technologies is immense, but many conditions are required for this potential to become a reality in classrooms and schools.

In glancing through the various works cited, we realize that the new technologies offer many avenues for reflection. One of them particularly attracts our attention. It can be stated as follows: could new technologies, when they are correctly used, alter a student's relationship with knowledge and learning so deeply that it becomes particularly difficult to pinpoint the learning achieved-or not achieved-in a specific discipline? In simpler terms, we might ask ourselves whether all learning achieved by relying on the powers of new technologies does not become in some way "holistic."

Among the conditions that lead to effective use of new technologies, the following can be considered as prerequisite : the effect of computer-based learning technologies in facilitating student learning and performance is seen only when participants have the knowledge and skill to use the technology. This observation may seem too obvious to be worth mentioning; however, many of the early investigations of the effects of computer-based learning technologies in the classroom did not deal explicitly with the knowledge and skill base necessary for the use of the technology, perhaps because of the assumed power of the technology. Those studies which do deal with this issue, both for students and for their teachers, show a marked contrast in student learning achievements compared with studies that do not treat the issue.

a) With respect to student knowledge and skill in the use of technology a study by Joram, Woodruff, Bryson and Lindsay (1992) contrasts with one by Owsten, Murphy and Wideman (1992). Both studies examined the impact of graphical-interface word-processing software on grade 8 students' writing and revision. In the Joram et al study, students used a word-processing program on which they had minimal training (approximately 10 hours, see Joram *et al,* p. 174); in the Owsten et al study, students used a word-processing program with which they had over a year's experience (approximately 100 hours of composing time, see Owsten et al, p. 254). For both studies the comparison was within students in that each student wrote and revised a composition by hand and using the word processor. In the Joram *et al* study, there were no differences in rated quality of compositions written by hand versus by word processor. In the Owsten *et al* study, quality ratings favored compositions written by word processor on both holistic and analytic assessment scales.

b) Referring to experiments and various sources, With respect to teacher knowledge and skills, successful implementations of computer-based learning technologies are associated with trained and knowledgeable teachers in the classroom. This is the case for large-scale projects where there is a major emphasis on dissemination of the technology (such as the Jasper video materials software developed by the Cognition and Technology Group at Vanderbilt University, 1996), and for smaller-scale projects more oriented to applied research in the classroom (such as Riel's work in which teachers act as action researchers, see Riel, 1990, p. 260). This emphasis on a knowledgeable teaching core stands in contrast to earlier approaches that were less successful in demonstrating learning outcomes where classrooms were simply provided with the technology for computer-based learning (see, for example, Seever, 1992, with the Magnet schools project, and Baker, Gearhart and Herman, 1994, with the Apple Classrooms of Tomorrow).

The efforts of the Vanderbilt group provide a model of the type of large-scale professional development and ongoing support for the use of learning technologies that leads to successful learning outcomes for students. Development activities consist of a two-week summer institute for participating teachers which covers: i) the Jasper materials and associated pedagogical approach, ii) the characteristics of the computing system, and iii) multimedia competencies (e.g., scanning, sound recording, etc.). Ongoing support is provided by personnel seconded part-time from technology companies and by electronic access to the network of participating teachers and researchers. The outcome is a group of teachers who are knowledgeable about the content and functioning of the computer-based learning technology; the outcomes for students are significant increases in their understanding of mathematical word problems as well as increases in number of accurate solutions to the problems in comparison with performance by control group students.

1. Specific Learning Achieved

This theme essent ' covers the knowledge, skills and attitudes the school system considers a formai part of its e ational mission. The research findings concerning student learning have been assembled around two subthemes: the development of various intellectual skills, and the specificity of learning using the new technologies.

IRST OBSERVATION :

The development of various intellectual skills

New technologies have the power to stimulate the development of intellectual skills such as reasoning and problem solving ability, learning how to learn, and creativity.

Reference points

a) By participating in scientific experiments conducted jointly with students in other schools and by drawing their information from various sources for the execution of their projects, using powerful telecommunications networks, students "learn critical information-age skills" and "build higher-order thinking skills" (Newman, 1994, p. 58).

b) Referring to experiments and various sources, the report published by the Office of Technology Assessment in 1995 put the emphasis on the relationship between the use of new technologies and preparation for a world in which such technologies will probably be quite commonplace. "Not only do technologies allow access to a broader range of instructional resources, but they also offer students the opportunity to learn to use electronic tools to access information and develop research skills using the technologies they will face in the future" (US Congress, Office of Technology Assessment, 1995, p. 59). The whole report is based on a comprehensive analysis of research findings published on this subject over the past 15 years, case studies, visits to schools in 12 states and the District of Columbia, a dozen funded studies and extensive consultation with teachers, students, education researchers and school administrators (see idem, p.7 and 51).

c) Enhanced student reasoning skills have been demonstrated following use of the *Archaeotype* multimedia software (Wallis, 1995). This software simulates an archaeological site in Assyria and allows small groups of students, for example, to dig at the site, discover artifacts, send them to a laboratory for measuring and weighing, and develop hypotheses on the culture of the society that inhabited this site (see Semel, 1992, p. 109). The assessment was conducted by comparing the group of grade 6 students with a control group in an equivalent private school. It covered students' analytical skills and was based on a simulation activity not familiar to either of the two groups. The findings were very favourable to the students who had used the software. In fact, they were found to be twice as skilled as the control group at developing and defending an explanation based on data.

d) In a series of studies, Scardamalia and Bereiter and their colleagues have examined the effects of their CSILE technology (an acronym for Computer Supported Intentional Learning Environment) on student achievement in the upper elementary grades. CSILE is a computer program that is designed to support the public development of knowledge in the classroom. Users, both students and teachers, can create and post text and graphic productions for others to view and react to. The function and role of these postings is supported by CSILE prompts. In addition the program maintains links among the postings and provides structural support for displaying and searching the links. The learning environment thus supports the development and presentation of student productions (both individual and collaborative) assisted by explicit peer and teacher feedback.

The outcomes for student learning using the technology have been assessed in a number of ways. Most significantly, different pedagogical uses of the technology have shown differences in student performance on strategic skills: A comparison was made of initial project planning by students who worked collaboratively using CSILE versus students who worked independently using CSILE. The former students showed more planning oriented to determining explanations of phenomena as opposed to basic facts (Scardamalia, Bereiter, Brett, Burtis, Calhoun and Smith Lea, 1992).

e) The Cognition and Technology Group at Vanderbilt (1991, 1996) have used action adventures presented by video media (tape or disk) to facilitate upper elementary students' solution of mathematical word problems. An emphasis is placed on the use of complex, realistic situations of information presentation, both to motivate the students and to foster more applicable knowledge and skills about mathematical problem solving. For example, the initial problem presented the main character, Jasper Woodbury, in a situation where he had purchased an old motor boat, and had to determine whether he could sail it back home given limitations on fuel, effects of currents, and limited daylight.

Because of this complexity the types of skills that students learn with these materials go beyond the usual computational skills for such problems. Typically, students must construct a plan for determining what information they need to abstract from the video to solve the problem (e.g., the capacity of the gas tank, fuel consumption, current directions, etc.). In addition students must structure the problem by creating subgoals that will help to solve the problem (e.g., is the tank capacity enough to allow a passage without refueling?). Groups using the video materials showed substantial gains in planning skills and the construction of subgoals for mathematics word problems compared both to their own performance at the beginning of the year to performance of students following a traditional mathematics curriculum (Cognition and Technology Group, 1996).

f) Math and science are two subjects in which professional associations and teaching staff in schools and faculties of education actively promote the use of new technologies for teaching. Padrón and Waxman (1996) comment on some large-scale experiments that illustrate ways of integrating the new technologies into math (see also Lei, 1996) and science teaching. In math, for example, they cite the videodisk series "The Adventures of Jasper Woodbury" from the

Cognition and Technology Group at /anderbilt University, which teaches children to solve complex problems using real-world simulations, in a climate of cooperation between teachers and students, and *Preparing for Calculus,* a more recent multimedia program considered to show promise. In science, they note the *Image Processing for Teaching* project which allow students to generate or manipulate images on a particular subject that they can observe, enhance and magnify as well as solve real-world problems; they also note the *National Geographic Kids Network* (see Sixth Observation, a) and *Science Vision,* in which students learn to master science by experiencing it as a process. These various projects are designed to replace the teaching of isolated facts with a constructivist approach to teaching science, development of curiosity and interest in science, and use of technology for scientific exploration. Thus, the new technologies provide opportunities to "explore" and "do" science rather than passively learning it. Padrón and Waxman conclude that the new technologies are capable of improving and enriching traditional instruction in math and science and, more significantly, of profoundly transforming this instruction in urban schools, where modernized instruction is most needed.

SECOND OBSERVATION :

Specificity of what is learned using the new technologies

The new technologies can contribute in several ways to better learning in various subjects and to the development of various skills and attitudes. The nature and breadth of learning depends on previously acquired knowledge, and on the type of the learning activities using technology.

Reference points

a) During the 1970s and early 1980s, many assessments were conducted of the effectiveness of computer-assisted instruction (CAI) compared with the traditional form of teaching. During this period CAI was used primarily to give students drill-and-practice exercises and feedback in basic knowledge and skills such as number facts in arithmetic and sight word recognition in reading. Assessments of the learning outcomes of CAI compared with traditional methods of instruction have consistently shown the superiority of CAI (Kulik, Kulik and Bangert-Downs, 1985; Herman, 1994).

b) By using a word-processing software, a group of grade 2 students improved general writing skills, while writing longer compositions than students in the control group who used traditional paper and pencil tools (Jones, 1994). The experiment was continued by reversing the status of each group. When the children returned to pencil and paper writing the first group of students continued to write well while the former control group in turn acquired the same writing skills as the initial group.

The characteristics of a word processing software effectively lead students to focus more on the actual content and editing of a text. Once students have acquired this skill, they also use it with more traditional tools. Through greater metacognitive and metalinguistic awareness, writing with a computer can also give students an incentive to think about language and to better assess the suitability of the terms they use.

c) In a series of studies, Riel and her colleagues have examined the use of networked computer-based communications systems by students in upper elementary grades as part of the language arts curriculum (see Riel, 1990). In one of these computer projects which lasted a school year, students at various sites in the United States jointly created a 'Computer Chronicles Newswire', reporting local stories and events to their distant student counterparts. The composition curriculum in the classes emphasized authentic composing tasks (i.e., for the Chronicles) and provided extensive practice in editing of other students' compositions. At the end of each school year students were tested for basic literacy and mathematics skills using the Comprehensive Test of Basic Skills. A comparison of performance on the CTBS at the end of the Chronicles year with performance at the end of the prior year showed that students had gained an average of three grade levels in language mechanics and two in language expression; however performance on reading and mathematics content showed a gain of about a year (as would be expected). In another project, students in upper elementary school corresponded for a year with faculty and students at university and secondary school levels in an electronic forum that explored a range of scientific and social topics. Standardized reading and writing tests given to the students showed that at the end of the year, student performance in reading comprehension was two years above grade level, and reading vocabulary and written expression were 1.5 years above grade level. However, both spelling and mechanics were less than a year above grade level. These findings, with reading performance being the highest, appear to reflect the nature of the students' participation in the forum -- as younger students working with adults and older students, they read many more messages than they contributed.

d) Learning outcomes from the CSILE environment (see First Observation, d) have shown the specificity of achievements using computer-based technologies. On standardized measures which assess basic literacy and quantitative skills (the Canadian Test of Basic Skills), CSILE students exceeded a group of control students on language measures, but showed equivalent performance on mathematics measures--an outcome which reflects the use of CSILE primarily for subject matter domains such as social studies which rely heavily on language (Scardamalia, Bereiter and Lamon, 1994).

e) In a study conducted in New Zealand, the use of computing technology contributed, with other teaching innovations, to greater learning in English, mathematics, and science (McKinnon, Nolan and Sinclair, 1996). Participating students were followed during grades eight, nine and ten. The educational project was characterized by three features: use by each student of a computer for at least three hours a week, extra-curricular activities, and the integration of basic subjects (English, math, sciences and social sciences). It was also based on several teaching principles and strategies generally recognized as effective in the current body of knowledge on education: learning activities focusing on real-life problems and situations, an interdisciplinary approach in conjunction with these problems and situations, teaching focused on the mastery of learning, and a combination of work in small groups and individual work. To judge true academic learning, researchers relied on the English, math and science examinations of the National School Certificate. The participating students performed significantly better on the Certificate examinations than students who had not participated in this project.

f) The learning outcomes from the Jasper Woodbury video and software programs (see First Observation, e) showed specific effects of student learning. The experimental group demonstrated gains in planning skills and the construction of subgoals for problems compared to students following a traditional mathematics curriculum. However, computational accuracy for both the experimental and the control groups improved by the same amount. Overall, the video groups solved more word problems because of more accurate problem representation (Cognition and Technology Group, 1996).

2. Student Motivation

New technologies manage to develop students' interest in learning activities, at least for the time being, and to lead them to devote more time and attention to these activities than in regular classes. This is clearly the case in the two observations highlighted below. Moreover, it is not too surprising that they also increase their confidence in their abilities. In turn, this confidence of the students in themselves undoubtedly explains in part the spontaneously receptive attitude that a large number of them adopt toward an activity in which technology plays a role and the perseverance that they show in accomplishing this activity. Of course a high level of motivation generally facilitates learning; but it is especially important in situations like the new technologically-based learning environments where students are more active in directing own learning.

THIRD OBSERVATION :

Interest in a learning activity

Most students show greater spontaneous interest in a learning activity that uses a new technology than in the traditional approaches in class.

Reference points

a) The Center for Research, Evaluation and Training (CREATE), in Burlingame, California, in cooperation with Apple, conducted a three-year study on the role of educational technology in the reform of education for children in kindergarten through 2nd grade classrooms across the country. In the first year of this study, four schools in four different states were closely studied; these schools use, in conjunction with other teaching resources, Apple's teaching software Early Language Connections (ELC) for teaching various aspects of language, primarily reading and writing. Throughout the year, investigators met with the students and the teaching staff of the 50 classes.

One of the main conclusions regarding the students is that they "are drawn to technology and are intrinsically motivated to use computers. At each site we visited, we saw students who were always eager to have their time at the computer, whether to complete an assignment from the teacher or to engage in activities of their choice. When children were offered a choice of many classroom activities, computers were always the most popular option. Teachers told us that children's productivity had gone up and that students' composition were now longer and better." (Guthrie and Richardson, 1995, p. 16. On this last point, see also Dwyer, 1994, p. 6 and the references mentioned in note 4).

b) The substantial report published by the Office of Technology Assessment in 1995 confirms the motivation effect that the use of technology has on students of all ages (see US Congress, Office of Technology Assessment, 1995, p. 65-66). Among the reasons that contribute to student motivation, there is the fact that technology "can be a key vehicle for stimulating learning, primarily because it creates environments and presents content in ways that are more engaging and involve student more directly than do textbooks and more traditional teaching tools." (idem, p. 65), that it possesses an "interactive capacity" (ibid.) and that it allows students to take part "in activities that invite them to create and share with others" (p. 66).

c) A study conducted by Altun (1996) among junior secondary students demonstrates in a different way tne interest that technology creates among young students. The anxiety felt by the students learning science using an interactive video was measured Given the circumstances, it is necessary to understand the interactivity of the material made available to the students: using a light pen, the students could make images, sounds, figures and text appear, but they could not use the "next," "back," "freeze frame," and "slow motion" functions of the machine.

The anxiety rate was low. This was true of girls as well as boys, as well as students rated strong, average or weak by their teacher (even though the group of strong students displayed a slightly higher degree of anxiety than the other two groups). These results are attributed to the user-friendliness and, genuine although limited, interactivity of the technology used. For example, Altun emphasized that for young learners the use of a light pen to make various types of images appear could have been viewed as "fun and motivating." "Moreover, the threat of making mistakes could be reduced to a low level by the availability of the repetition function that permits students to repeat any parts of the program as many times as wanted." (p. 310).

d) Underwood, Cavendish and Lawson (1996) have conducted an assessment of an integrated learning system, *CCC's Success Maker*, used in a group of elementary and secondary schools over a period of two years. According to the authors an integrated learning system has three essential components: a curriculum content, a record system and a management system. In addition to offering students a wide variety of learning activities, such a system records and interprets their responses to the task in hand, providing them with performance feedback; the system also updates their files, which can be accessed by the teacher, who can thus make individualized teaching interventions.

The findings of this assessment show that after two years the students were still interested in working with the system. A teacher summarized the situation on this point as follows: "the students like competing against themselves and that they were also happy to tackle new things because they were in a non-threatening, non-judgmental environment. Although she perceived that the system corrected, even punished, errors it was 'not personally offensive as it often is in the classroom'." (p. 958).

FOURTH OBSERVATION :

The time and attention devoted to learning activities

The attention span or concentration that the majority of students are willing to devote to learning activities is greater when they use a new technology than when they are in a traditional setting using traditional resources.

Reference points

a) Many integrated learning systems exist in which the computer plays a key role. These systems aid the teaching of one or more subjects and help develop the students' various skills. They usually include a learning management program; the presence of such a program would even constitute "one essential feature" (Van Dusen and Worther, 1995, p. 28). The type of lessons and other resources that these systems offer the students depends to a great extent on the learning concept on which they are based (behaviorism in one case and constructivism in another, for example).

According to the findings of a two-year study conducted throughout the United States and confirmed by specific studies in several school districts, these systems are very often underused or used incorrectly. However, in cases (still very few), in which they are implemented properly, "they do produce positive results. Indeed, they have the potential to transform the classroom into a better environment for learning." (idem, p. 30). Of all the areas in which change could occur, the time students concentrate on a learning activity heads the list. Because they love working with a computer, because they can progress at their own pace and because they receive immediate feedback on what they are doing, "the students remain engaged" (ibid.). According to this study time-on-task is on average 20 percent higher when an integrated learning system is used correctly than in a traditional classroom setting (p. 31).

b) Collins (1991) notes eight trends that he describes using existing documentation and his own observations in schools. One of these focuses on the increased participation of students in their training: "In settings in which computers have been put at the disposal of students as part of some long-term activity or project, researchers have reported dramatic increases in students' engagement." (p. 29). When the students performed a learning activity on a computer, the researcher notes that they were willing to devote more time and energy to it. (see idem, p. 30).

3. Relationship of Students to Knowledge

With the benefit of a more comprehensive inventory, it is evident from the research conducted that it is difficult to talk about the contribution of new technologies to the students' genuine learning without remarking that they cause significant changes in the very way in which students approach knowledge and incorporate it into what they already know. At least, this is what the content of the three subthemes of this section point to based on concrete experiences. The three themes are: developing the research spirit, greater cooperation among individuals, and more integrated and better assimilated learning.

FIFTH OBSERVATION :

Developing research spirit

The new technologies have the power to stimulate the search for more extensive information on a subject, a more satisfying solution to a problem, and more generally, a greater number of relationships among various pieces of knowledge or data.

Reference points

a) Lafer and Markert (1994) have assessed the inquiry activity of elementary school students using the *Lego TC Logo* package in their science curriculum. This package includes the well-known Lego construction blocks, complementary items (wheels, electric motors, electronic sensors, etc.) and computers. In small groups, the students build a machine and use the Logo language to design programs that control it. The objective of this activity is to familiarize students with the basic concepts of both engineering and computer programming. Assessment of the activity was based on the recording of conversations among students made while they were working in groups, observation, the analysis of notebooks, and interviews with the students and teaching staff.

A student builds some sort of vehicle and expects it to perform a certain number of laps on a given circuit. It does more! Why? This is one example of many of a situation that piqued the curiosity of participants. To solve the "problem," the student has to gain a better understanding of what is happening and to collect new information. Thus, to meet the objectives they set themselves, the students must constantly adjust the construction of their machines and the computer programming. Lafer and Markert described the students' desire to find a solution as apparently strong (p. 86). The students "are truly perplexed" when something does not work the way they had expected it to (idem, p. 87); this "drives them to continue their research to find a solution" (ibid.). The researchers responsible for the assessment conclude that "there was evidence in the observations and transcripts that the activities caused students to seek information and to apply prior learning to accomplish the goals the activities set before them." (p. 91). The overall results of the assessment indicate that, on the whole, *Lego TC Logo* is an excellent means of creating a "genuine" learning situation, that is, a situation that students perceive they are able to change by the decisions they make and the actions they take. To be more precise, these findings show, inter alia, that *Lego TC Logo* has the capability to develop a research spirit in students and even more so it appears, an attitude of interdependence (on this latter point, see the Sixth Observation, c).

b) Heidmann, Waldman and Moretti (1996), who helped develop the Archaeotype multimedia software (see First Observation, c), give the following summary of how they view the contribution of such software to the development of the research spirit in students: "Multimedia technologies enable the creation of environments in which constructivist learning can take place. They make available to students original materials instead of pre-interpreted and diluted information. They provide tools for the exploration of that data so that students can investigate a topic and approach it with genuine questions. In the process students create new and examine existing knowledge structures through the exploration of a topic as well as an appreciation of the it." (p. 301).

c) Assessments of the effects of using computing technology the classroom carried out by McKinnon, Nolan and Sinclair (1996) in New Zealand, in addition to examining learning outcomes (see Second Observation , e), also examined the motivation of the students, and their attitude toward using computer technology. Results indicated that the use of the technology did contribute, with other teaching innovations, to the development and support of this intellectual curiosity and this research spirit deemed so important in the education of young people.

One of the main conclusions that the researchers highlight in their study is the following: "sustained computer use enabled students to become not just "technologically literate" but it also enabled them to become producers of knowledge as they analyzed data and information and developed testable propositions." (p. 465). The authors also pointed out that through this project, "teaching and learning processes occurred which are not commonly found in traditional secondary school classrooms." (ibid). Finally, inspired by John Dewey, they noted, inter alia, that the students involved "tended to regard their work as a public activity available for scrutiny and constructive comment by teachers and peers" and that they, as well as their teachers, agreed to recognize that the "students need to be actively and, when appropriate, collaboratively involved in the construction and testing of their own knowledge" (ibid.).

SIXTH OBSERVATION :

Broader cooperation among individuals

The use of new technologies promotes cooperation among students in the same class and among students or classes in different schools, near or far, for the purpose of making them more aware of other realities, accessing relevant knowledge not strictly defined in advance, and executing projects with a genuine relevance for the students themselves, and possibly for other people.

Reference points

a) Use of the computer in conjunction with one or more computer networks outside the school has numerous benefits. Thus, as demonstrated by the popular *National Geographic Kids Network*, in which students conduct scientific experiments while gathering data useful to current research, "joint projects are possible between schools.... Likewise, students and teachers can immediately obtain information about their projects from a wide variety of sources" (Newman, 1994, p. 58).

b) The first phase of the Apple Classrooms of Tomorrow (ACOT) project ran 10 years (1985-1995). It started in seven classrooms in seven different elementary and secondary schools in 1986. The number of schools and classes varied somewhat thereafter. Although the project made intensive use of computers and a wide range of software, several traditional teaching methods and resources continued to be used, especially in the early years (textbooks, direct instruction to the entire group, etc.). This project gave rise to several assessments by researchers from Apple as well as other organizations, and included systematic monitoring (see Dwyer, Ringstaff and Sandholtz, 1991, Dwyer, 1994, and West, 1995).

One of the most striking and consistent results of this experiment was that use of this technology did not isolate students from one other. but instead increased the relations between them. Cooperation in a wide range of learning activities, often intellectually demanding and involving a certain scope and time, over the years actually became one of the main characteristics of the ACOT project. This evolution led in part to a lasting work atmosphere, an arrangement of time devoted to educational activities more respectful of individual paces and the nature of the activities, and a growing number of links between subject matters and with reality (see idem).

c) The assessment of *Lego TC Logo* (see Fifth Observation, a) carried out by Lafer and Markert (1994) led to at least partly similar findings on cooperation between elementary students. To harmonize the operation of machines built with Lego blocks with complementary material and computer programming, the participants had to learn to resolve conflicts and help one other. The strong desire to find solutions for the problems encountered enhanced the interdependence and cooperation among the students. Each became a resource both for discovering the causes of these problems and for finding solutions.

The researchers noted that there were some conflicts between students but stressed that such social interactions play an important role in development of the ability to think. "Without competing ideas to weigh, there is little to compel one to critically examine the views one holds," they explain (Lafer and Markert, 1994, p. 89). The researchers also were especially struck by the fact that through this experiment, the students learned to cooperate in learning situations that had meaning for them. They point out that this cooperation "evolved as a response to a need... It was understood as a way to get a job done" (ibid.). Consequently, they not only "acquired" the standards inherent in cooperation, they also "actually acquired them" through real situations (ibid.).

d) Brownell and McArthur (1996) have presented findings from their assessment of a similar experiment conducted in a grade 6 class using *Lego Logo* software and hardware. Through this experiment, she wanted to initiate the students to the concept of robotics, make them practice certain math skills and give them an opportunity to work in teams (virtually a new experience for this group of students). Each day for four weeks, the students, divided into groups of two to four, were given time to make a moving object that had to serve a specific function. The researchers gathered data in two ways for the assessment: through observation in the classroom and through interviews with all the students and the teacher. The findings, although still preliminary, show that for the teacher as well as the students, one of the main areas in which learning occurred was that of social interaction (p. 271)

e) Most educational software is designed for individual use. In schools, however, all the hardware for this is not always available, so two students may be asked to work together on a single computer. In this setting, it becomes particularly important to characterize the interactions that occur between the students themselves, as well as those between students and the learning environment made available to them (primarily the computer and a control device, but also the instruction and work sheets).

McLellan (1994) reported a fairly large scale study of student to student interaction using computing technology. In 38 US secondary school students registered in an astronomy laboratory course worked with a simulation software called *Sky Travel*. In pairs, with a partner of their choice, they conducted a series of observations, interpreted them, identified the common points between the phenomena studied, and developed hypotheses. To gather as much data as possible on the students' interactions, both social and with an object in the learning materials, several different methods were used: systematic observation, interviews, etc. The 23 types of interactions identified were grouped into four categories, characterized respectively as verbal communication, a gesture or action of the arm or hand, a movement or special attention paid to a given object (e.g., reading a sheet of instructions), or nothing in particular. Separate consideration was given to the fact that in most cases, one partner used the keyboard and control device much more often than the other.

Analysis of the results indicated that the exchanges between students were frequent and substantial, that when problems arose, a student turned first to his or her partner rather than to the teacher, and that the student who worked more often with the computer spoke more often to give answers or explanations while the other student asked more questions. Overall, the students focused on the work to be done and were distracted very little, even by their partner. However, the students who used the computer less were, on average, slightly less attentive than the others. The findings of this assessment also showed that the teams often entered into contact with those around them; for example, students stood up to go look or point at another screen and discuss the variations observed. After discussion, they occasionally input data to a neighboring team's computer. This was done to help each other, but also occasionally to make a simple verification. This approach considerably increased the information potentially available to the students to perform their work. This study therefore reveals that having two students work on one computer can prove very positive; it contributes in particular to developing the ability for social interaction, itself deemed indispensable for mastering certain intellectual skills and performing certain tasks.

f) One of the trends (see Fourth Observation, b) described by Collins (1991) gives a broader meaning to integration of the standards inherent in cooperation between students, mentioned at the end of paragraph c) above. This trend indicates that use of technology in the school system is likely to transform the current competitive social structure of the classroom into "a more cooperative social structure" (p. 30). Among the work cited in support of the author's statement is that in the Apple Classrooms of Tomorrow project (see above, b) and that by Scardamalia and Bereiter and their colleagues with the Computer-Supported Intentional Learning Environments (CSILE) project. Within this fairly developed environment, "the students comment on one another's notes, telling what they find interesting and what they cannot understand" (p. 30).

SEVENTH OBSERVATION:

More integrated and better assimilated learning

The potential for simulation, virtual manipulation, rapid merging of a wide variety of data, graphic representation and other functions provided by the new technologies contributes to a linkage of knowledge with various aspects of the person, thereby ensuring more thorough assimilation of the many things learned.

Reference points

a) In one of the secondary schools of the Apple Classrooms of Tomorrow (ACOT) project (see Sixth Observation, b), a group of students in the project was monitored from grade 9 to 12 to compare their learning with that of other graduates from the school. The results showed large differences in "the manner in which they organized for and accomplished their work. Routinely they employed inquiry, collaborative, technological, and problem-solving skills uncommon to graduates of traditional high school programs" (Dwyer, 1994, p. 8). Dwyer noted the relationship between these skills and those required in the work world proposed by the SCANS Commission (set up by the US Secretary of Labor; the Commission's report published in 1992 generated keen interest in both the educational and labor fields).

b) Barron and Goldman (1994) reported a broad consensus among specialists in prototype development and researchers in media integration on the following points: i) "the integration of video with text and information from other media creates a rich context for student investigation and problem solving"; ii) "nonlinear linking of information makes it possible for a topic to be examined from multiple perspectives, that promote retention and transfer"; iii) "when appropriate tools are available in the system, learners can create their own integrated media products, thus becoming involved in interpreting or producing knowledge" (p. 87). The authors conclude that a technology in which media are integrated "provides a richer base of information and a more effective vehicle for analysis and investigation than do linear videotapes, which are usually passively viewed" (p. 91).

II. THE CONSEQUENCES OF APPROPRIATE USE OF NEW TECHNOLOGIES ON THE TEACHING FUNCTION OF TEACHERS

Introduction

The three themes discussed in this part form the basis for a coherent schema describing the central function of teachers: teaching a group of students. These themes are preparation or planning for teaching, the actual teaching or work with a group of students, and the assessment of learning. These correspond to logical stages in the teaching activity, but are also aspects that overlap in many ways. The assessments and tests briefly cited in the following reference points appear to show that under the influence of new technologies, this overlap is increasingly common and complex.

In traditional teaching, a student's learning is largely dependent on the teacher's activity. What happens when the new technologies come into play? The first part of this documentary review has begun to answer this question by focusing on the student's learning; this second part focuses on the teacher's teaching activity. What are the impacts on this activity of using the new technologies? In what way and to what extent do they challenge the traditional content and forms of this activity? These are the key questions that define the area explored in this second part.

In many cases, the new technologies change very little in students' learning or in teacher activity, because only a very small portion of their potential is used (for example, see Ford, Poe and Cox, 1995). This is why we found it necessary in the title of this part to qualify as "appropriate" the use of the new technologies that will be the focus of our attention in this documentary review. However, this term must not be interpreted too strictly, because research is undoubtedly needed to establish what the expression "appropriate use" actually means.

4. Planning of Teaching

Given the documents surveyed for this report, two remarks may prove useful as background for this theme. The first is that in a large number of cases in which new technologies play a role, a portion of the usual planning activity, which may be substantial, is now shifting to places where courseware, video and documentary series, videodisks, integrated learning systems or other didactic resources are produced. The second remark repeats an observation found in one form or another in several of the documents cited in this report, which can be summarized as follows:

i) the benefit to students of using new technologies is greatly dependent, at least for the moment, on the technological skill of the teacher and the teacher's attitude to the presence of technology in teaching;

ii) this skill and this attitude in turn are largely dependent on the training the teaching staff have received in this area.

It must be noted, however, that a comprehensive review of these two broad topics -- the new locale for detailed planning of teaching, and the training of teaching staff -- lies beyond the defined scope of this documentary research.

Despite the previous remarks, the immediate planning of teaching -- that is the teacher's preparation of instructional tasks and materials for his or her students -- continues to be an essential theme. Further, this theme is comprised of three subthemes: i) the information on new instructional resources and the availability of support for their use, ii) the teacher's cooperation with other people, and iii) the orientation of planning.

EIGHTH OBSERVATION :

Information on new instructional resources and availability of support for their use

Through the new technologies, teachers quickly obtain information on the availability and value of a very diverse selection of instructional resources, and also often benefit from support for their use.

Reference points

a) In a chapter devoted to what technology promises for teachers, the report prepared for the US Congress (see Third Observation, b) indicates that the new technologies that allow teachers, for example, to save to memory in a few minutes an article published in that morning's newspaper and ask their students "to explore worlds beyond their immediate reach" (US Congress, Office of Technology Assessment, 1995, p. 59), "to peruse the card catalog at the local library for a list of books on a research topic" (ibid.), "to preview software to see if it is appropriate for students at a particular grade level", (ibid.), to establish contact, sometimes instantly and simultaneously, between their students and a poet, religious leader or other students located "down the block or on the other side of the world" (US Congress, Office of Technology Assessment, 1995, p. 60) or "to gain immediate access to classes sharing a common interest in a particular topic" (ibid.). Similarly, projects such as *Kids Network* (see Sixth Observation, a), *Global Lab* and *Kids as Global Scientists* "can supply the focus and boundaries for interaction and can provide teachers with the content, accompanying materials, organizational help, and technical assistance they may need to work telecommunications into their curriculum and lesson plans" (US Congress, Office of Technology Assessment, 1995, p. 61). Many other uses are possible (see idem, pp. 75-77).

NINTH OBSERVATION:

Teacher cooperation with other people

The new technologies facilitate the teacher's cooperation with colleagues as well as other people inside or outside the school system for planning or development of learning activities intended for students.

Reference points

a) Teachers are making increasing use of email (US Congress, Office of Technology Assessment, 1995): "Telecommunications use by teachers, especially for email, has expanded in the last few years, and with good reason: teachers with classroom access to local or external telecommunications networks can contact other educators, experts, scientists, and practitioners to discuss issues related to their teaching practice, developments in their field, and classroom experiences. Furthermore, a growing number of teacher-based networks offer teachers a chance to connect with other people in a variety of forms" (p. 78; see also pp. 55-56 and 87).

b) Initial results concerning teacher interaction via email on the Jasper Woodbury materials indicated a lower degree of use than had been expected (Cognition and Technology Group, 1996). Teachers participating in the implementation and assessment of the materials were provided with modems and commercial accounts for contacting each other and university and business participants in the study; however, teacher use of this service was minimal. This outcome suggests that effective and sustained use of such a communication technology depends not only on the technology but also on perception by the participants of an actual community of instructors working with and developing curriculum that uses learning technologies.

TENTH OBSERVATION :

The orientation of planning

The teacher's planning for teaching requires great harmony between his or her orientation towards teaching, expected learning outcomes, and the characteristics of the technologies he or she utilizes. Hence, the likelihood of positive results is enhanced when the teacher places great importance on the development and arrangement of activities whose execution requires students to perform real work and cooperate with other students.

Reference points

a) The study of the design of computer-based learning technologies p; that is, the structure of presentation features and functionalities of the systems p; remains an emerging field. For example, Collins' (1996) examination of issues in the design of learning environments presents a number of substantive considerations that educators ought to consider in constructing or selecting an environment, such as whether the environment is to support breadth or depth in student knowledge; however, almost all of these issues (as Collins indicates) are general ones that should be considered in the design of any learning environment, whether computer-based or not.

To be sure, systems exist that link educational activities with functionalities of software. For example, in Peled, Peled, and Alexander's (1994) taxonomy, the mastery of basic knowledge is linked with drill and practice software because of software features such as extensive structuring of information for the user and programmed feedback on user accuracy in performance. At the other end of the scale, the taxonomy links educational activities involving analysis and synthesis of knowledge with open tools such as word processors because of features such as user provided content. These taxonomies are valuable for a general classification of software for different educational activities; however, the issue for studies of design is how to promote different kinds of learning by means of features incorporated into the technology.

Some examples of the pairing of expected learning outcomes with specific technological features include the following: First, Riel's (1990) research showed that writing a story for a real audience by using computer-based communications increased the quality of text produced as compared with writing a story for the purposes of grading. In this case, the e-mail features of the computer system made the task authentic by providing a real reader for the story as well as the possibility of immediate response. Second, CSILE students' greater ability explain dynamic phenomena (such as continental drift) is related to the availability within the technology of a graphics program that can be annotated and linked to other text (Scardamalia, Bereiter and Lamon, 1994). Third, the higher performance shown by Jasper students in analyzing and understanding problems depends on the use of multimedia to present realistic problems of sufficient complexity that students can identify with characters in the problem (Cognition and Technology Group, 1996).

b) Both the CSILE and Jasper Woodbury learning environments have produced gains in students learning and performance and have explicitly incorporated computer-based features based on an analysis of intended learning outcomes. Thus the design of these environments merits further description.

The CSILE (Computer Supported Intentional Learning Environment) software reflects a pedagogical emphasis on participatory knowledge building by students and teachers, and is thus an open system which participants use to input and cross-reference content. The research of Scardamalia, Bereiter and their colleagues using the CSILE environment has become increasingly based on a pedagogy that seeks to foster knowledge building on the part of students that is sustained over time, leads to understanding of phenomena and issues that focuses on explanations of why they occur, and is capable of being applied in different situations. The analogy that Scardamalia and Bereiter draw on comes from the scholarly disciplines, where the building of knowledge is both a private and a public affair and is supported and demonstrated by public products as seen in publications, presentations, and courses and programs of study (Scardamalia and Bereiter, 1993).

In light of this perspective, they propose the following **design characteristics** for learning technologies, which they are implementing in CSILE:

i) Allow contributions that are either publicly accessible and credited to the author, publicly accessible and anonymous, and private. This allows access to the work of others in order to compare ideas and learn more advanced material. It also provides support for private reflection and refinement of ideas.

ii) Provide labeling, commenting, and linking facilities together with appropriate notification features. Such characteristics guard against information 'disappearing' into file or folder structures and thus not being available to students to support elaboration, consideration, or discussion.

iii) Support source referencing for contributors of products. This feature ensures appropriate attribution of a student's ideas and provides a historical record of knowledge building.

iv) Provide storage and retrieval capabilities that situate products in a communal context. The objective of this feature is to promote the linking of related ideas by students working on different aspects of a problem through the use of indices.

v) Allow varied types of entry into the technology for users different ages and levels of sophistication. This characteristic, realized through the use of icons and simple two-word texts, promotes accessibility to the technology and the evolving public knowledge base.

vi) Support coherence of information and deal with information overload. This feature allows products to be tagged, linked, subordinated, etc. as students use them in knowledge building activity. At the same time, monitoring by the system should inform students about contributions that are not being used, so that such contributions can be deleted or returned to private status.

vii) Provide facilities to access remote knowledge sources. This feature, realized through network and CD-ROM capabilities, places student knowledge building within an expanded and more authentic knowledge building community that includes public institutions such as museums, the world of business and work, and the home.

c) In contrast, the research project of the Cognition and Technology Group at Vanderbilt (1991) reflects a pedagogical emphasis on understanding and solving complex and applied mathematical problems, and thus is a much more structured system than CSILE with respect to the content that is presented. The research group initially focused on students in grades 5 and 6 who were having difficulty with reading and mathematics, with a particular focus on fostering student understanding of mathematical word problems in which one has to work with speed, distance, and time quantities (e.g., if a bus travels at 100 km per hour, how long will it take to go the 500 km from Montreal to Toronto?). More recently this focus has broadened to encompass support for students' understanding and solving of problems in much more complex and realistic situations, where solving the problem requires inquiry and planning on the part the students as well as formula application and number computation (Cognition and Technology Group, 1996). The Vanderbilt approach is implemented in the Jasper Woodbury Adventures series of videos and associated materials and exercises. The approach is based on the following **design principles**:

i) Present realistic problems set in realistic situations. This principle is realized primarily through the use of video media (either tape or disk) which presents live-action characters (e.g., Jasper Woodbury) tackling specific problems such as whether they have enough fuel to rescue a rare and endangered bird at a remote location. The principle realizes a number of outcomes: First, it promotes student interest and identification, primarily through the use of a narrative format that presents a problem in which students (at least vicariously) can see themselves participating. Second, through the use of what is essentially a multimedia format that combines verbal and visual information, more complex problems can be presented in an understandable way to students. Third, the detailed and realistic background information that is presented as an integral part of a video can serve as the starting point for problems in content areas other than mathematics.

ii) Embed all required data in the presentation. This principle insures that the presentation contains information sufficient to solve the problem, and basically realizes the integrity of the presentation for the students in the sense that they come to know that working with the content of the video can lead to a realistic solution.

iii) Present complex problems. Each situation involves a problem of multiple steps and usually allows more than one solution. This principle promotes student mastery of complex problems which are more closely related to problems they will encounter outside the classroom, and thus authenticates the computational knowledge and skills learned.

iv) Structure problems to realize a generative format. Although the presented information is sufficient, problems are structured so that students must generate intermediate steps for a solution. This principle promotes student engagement with the problem, and emphasizes the importance of planning and inquiry skills for understanding and solving realistic problems.

v) Provide linkages across subject areas. The complexity of the problems is structured so that solutions require the use of different types of knowledge and skill, typically language comprehension, planning, statistics, geometry, and even geography, as well as arithmetic computation. The principle thus supports the integration of student knowledge and skills.

vi) Structure presentations to promote transfer across situations. This principle is realized through the development of pairs of adventures around the same mathematical themes (e.g., problems of speed, distance, and fuel consumption). The pairs of adventures support student application of the knowledge and skill they have abstracted in an appropriate manner to new but related situations.

d) The issue of design of learning technologies can be addressed at two levels (Reusser, 1996). The general level, reviewed above, has shown that design characteristics of learning environments reflect characteristics of the pedagogy that teachers adopt. A more particular level has to do with the design of software for teaching specific content or skills. At this level, the design depends on a careful analysis of the knowledge that one expects students to learn and apply as well as consideration of the sequence of presentation of this knowledge in order to facilitate mastery. The study summarized below indicates the issues involved.

i) A study by Jackson, Edwards and Berger (1993) investigated the design of graphing software that was used in the development of curriculum to teach secondary students how to analyze and present data graphically. Experimentation with commercially produced software indicated that the major problem in the structure of this software concerned the "front-end loaded decision structure" (p. 425) required for using the software. That is, effective graph production required a sophisticated level of user knowledge about graphing in order for the user to make decisions such as how to configure complex options concerning scale characteristics of the axes prior to producing the graph. Such software thus realizes a sophisticated tool for the expert, but leaves the less knowledgeable student lost in a maze of choices.

Jackson *et al* then designed a specialized software program that provided perceptual support for the knowledge that students were to apply in producing graphs. One major design feature was the placement in a single window of the choice of graph type (i.e., column, line, pie chart) and the choice of variables for the horizontal and vertical axes. The juxtaposition of these choices is a critical aspect of graphing since the characteristics of the variables (i.e., either numerical or categorical) restricts the choice of type of graph. (For example, a categorical variable such as geographic region on the horizontal axis rules out the use of a line graph.) Another design feature was the sequencing of choices concerning scaling characteristics of the axes (i.e., maximum and minimum values for a vertical axis). This design feature achieved two objectives: First the sequence of presentation of choices by the software corresponds to a sequence of decisions by the student. Secondly, the student can examine the effects on the graph of different decisions at any point in the sequence, thus showing a particular graphical outcome to be the result of a specific decision.

The issue remained of how to embed the graphing software within a particular pedagogical approach. Jackson *et al* focused on issues of feedback and flexibility, creating three different presentation modes for the software: A restrictive mode disabled choices on the interface given prior decisions by the student; an open mode allowed all possible choices; and a coaching mode allowed all possible choices, but advised students by means of pop-up help notes of the implications of certain decisions. Student experience with the software consisted of about six hours of practice on graphing exercises. Learning was measured, not directly in terms of using the software, but on a transfer task using a series of problems in which students critiqued graphical presentations and suggested improvements. Results showed that the students in the coaching mode outperformed both the restrictive and open modes. Observations of student performance and subsequent interviews suggested that the combination in the coaching mode of being able to explore graphing outcomes together with feedback on the implications of decisions facilitated learning, thus highlighting the significance of student activity and participation in learning even for a content such as graphing that is primarily a skill area.

ii) A study by Kozma, Russell, Jones, Marx, and Davis (1996) investigated the design of software to illustrate for **undergraduate university students** the chemical phenomenon of dynamic equilibrium between different colored gases. The software was designed to support student learning of an expert's model of gas equilibrium, and in particular the knowledge that, although at the general physical level two gases will reach a state in which they maintain a constant proportion to one another at a given temperature, at the molecular level molecules of one gas continue to change into the other and vice versa. Hence the term 'dynamic equilibrium.' The software presented a number of linked representations illustrating the phenomenon, including: i) A video window displaying the physical apparatus (e.g., test tube containing the gas mixture, water bath for heating, thermometer, etc.) and characteristics of the phenomenon. The sequence of the video showed a change in the color of the gas mixture (from pink to red) as the mixture was heated; ii) a graph window showing the proportions of the two types of gases as a function of heat. The plots in this window were linked to the video window so that the software drew the graph in time with the video as the mixture was heated; iii) An animation window displaying symbolic molecules which moved, collided, and sometimes changed from on type of gas molecule to another. This window provided a perceptual representation of the expert knowledge of dynamic equilibrium. Again the window was linked with the other two windows--as temperature increased, the molecules of the animation window increased in speed, number of collisions increased, and proportions of changes from one gas type to the other corresponded to the color and plot characteristics of the other windows. This last window is noteworthy since it realizes a material representation of a phenomenon heretofore strictly mental.

The software was designed for different pedagogical approaches, from use as a display in lectures through exploratory work by students in a laboratory. Evaluation of the effects of the software has been carried out for the lecture approach using a pretest - post test format. Student knowledge of dynamic equilibrium was assessed prior to covering the topic in a regular chemistry course. Students then had two one-hour lectures in which the instructor used the software to illustrate aspects of the phenomenon, after which student knowledge was assessed by means of a post test. The results showed substantial gains in knowledge about the characteristics and processes of dynamic equilibrium (the average post test score was a standard deviation above the average pretest score). The study thus shows the potential learning gains for software that presents interconnected representations for expert knowledge.

5. Intervention with a Group of Students

The documentation consulted is virtually unanimous in stating that effective use of new technologies changes the function and work of teachers in the classroom. Many terms are used to describe the nature and scope of this change but almost all convey at least two ideas: part of the transfer of information inherent in teaching is shifted from the teacher to the technological media, and the teacher has more time to support each student in the individual process of discovery and mastery of knowledge, skills and attitudes.

This change, which is also influenced by other factors, leads to a different concept of teaching and learning, which become more akin to ongoing research and at the same time an eminently personal, shared approach.

These are the two subthemes examined in relation to the teacher's work with a group of students in an educational environment where new technologies play a genuine role.

ELEVENTH OBSERVATION :

Different relationships between teachers and students

If the new technologies are used in such a way as to exploit their potential, the teacher interacts with students much more than in a traditional classroom, as a facilitator, a mentor, a guide to the discovery and gradual mastery of knowledge, skills and attitudes.

Reference points

a) Research by Guthrie and Richardson (1995) on the use of microcomputers to teach language at the elementary level (see Third Observation, a) reported major changes in the teaching function of teaching staff. Thus, even if the microcomputer was used only for certain activities and was not mandatory at any time, "it allows for a more individualized approach to learning. Much of the software lets students progress and learn at their own pace, and teachers become more like facilitators and coaches who tailor their assistance to the needs of the child" (p. 16; in the same vein, see also the findings of the 1990 survey by the Center for Technology in Education at the Bank Street College of Education, in US Congress, Office of Technology Assessment, 1995, pp. 52-53).

b) Van Dusen and Worthen (1995, see Fourth Observation, a) also saw significant changes to the teaching function of teachers. They noted, "teachers are still responsible for students' learning, but rather than being dispensers of information they become guides to the learning process. They act as facilitators and organizers of learning activities..." (p. 32). Teachers were also more available to "coach their students in how to process information, helping them to make choices and validate their learning" (ibid.).

c) In the considerations on the contribution of technology to teaching and learning Means and Olson (1994) conclude that "Technology tends to support teachers in becoming coaches rather than dispensers of knowledge" (p. 201).

d) Altun (1996) in her research on the effects of interactive video (see Third Observation, c), pointed out that its for teaching science allows the teacher to devote more time to each student, especially those of low ability or unfamiliar with the new technologies (p. 310).

e) Similarly, Heidmann, Waldman and Moretti (1996) in their assessment of the Archeology multimedia software (see Fifth Observation, b) conclude that "use of new technologies allows the teacher to become a facilitator for the student in the 'process of discovery'" (p. 302; in the same vein, see also Padrón and Waxman, 1996, p. 197 and the unequivocal testimony by a teacher from the National Geographic Kids Network in US Congress, Office of Technology Assessment, 1995, p. 69).

f) Three of the eight trends identified by Collins (1991, see also Fourth Observation, b) directly affect the teaching function of teachers, and especially teachers' relations with their students (p. 29).

i) When teachers use the computer to teach, they tend to work with small groups of students or individual students rather than with the class as a whole at any given time. This allows them to develop a much more accurate and realistic impression of what students do and do not understand.

ii) Teachers become "coaches" instead of people who transfer information and then ask the students to regurgitate it. The computer plays roughly the same role as the piano: only by playing piano or working on a computer can a student learn; teachers serve as a guide to ensure that the interactions between the student and the piano or computer contribute to the student's learning.

iii) Teachers concentrate more on students who need help, who are usually the weakest, while in the traditional classroom, they tend to give priority to the strongest students.

TWELFTH OBSERVATION:

A different vision of teaching and learning

In a context where new technologies play an important role, teachers begin to view knowledge less and less as a series of facts to be transferred and more and more as a process of continuous research in which they share the

difficulties and results with their students.

Reference points

a) Successful computer-based learning technologies are a component of a larger pedagogical approach that warrants the use of the technology. Viewing computer-based learning technologies as a tool or instrument implies that there exists a pedagogical approach which is well enough articulated so that the inputting, presentation, and communication facilities of the computer are realized as effective aids to student learning and performance. Just as teachers must be knowledgeable about the learning technologies they and their students are using, they must also be knowledgeable and experienced in the pedagogical approach to be taken in their classrooms. This, of course, takes us somewhat beyond a consideration of the effects of learning technologies, but it would appear to be necessary if we are to determine i) how computer capabilities can be used to promote learning, and
ii) how to design computer-based learning environments.

To be brief, revised pedagogies are increasingly concerned with fostering learning and performance in students that is: i) 'higher-level' in the sense that students apply their knowledge to analyze, understand, solve problems rather than simply recall facts, ii) 'authentic' in the sense that it is relevant to student activities and situations beyond the classroom, and iii) 'independent' in the sense that students can apply their knowledge and skill as appropriate to different subject matters. These general objectives motivate a pedagogy in which students carry out and present projects (rather than, or in addition to memorizing facts), interact with peers, teachers, and other people beyond the classroom as both learners and sources of information, and are responsible for planning activities and coordinating multiple sources of information in the pursuit of knowledge (see Brown and Campione, 1996).

b) This revised vision is manifest in the assessment conducted of the Apple Classrooms of Tomorrow project (see Sixth Observation, b) by Dwyer, Ringstaff and Sandholtz (1991). Over the years this in-class experiment ran, teaching staff gradually and more substantially revised their ideas about teaching and learning. Even by the sixth year, these teachers apparently were "more disposed to view learning as an active, creative, and socially interactive process than they were when they entered the program. Knowledge is now held more as something children must construct and less like something that can be transferred intact" (p. 50). This change was confirmed again later. Instruction had become "construction" in which the interpretation of facts replaced their accumulation; comprehension of the subject matter covered replaced its volume; and assessment of the ability to do or demonstrate replaced multiple-choice questions.

c) According to Collins (1991, see Fourth Observation, b), the introduction of new technologies in schools will also have a notable influence on our actual conception of teaching and learning. Now, in principle at least, students all learn the same thing in the same way at the same time, whereas the new technologies make different learning patterns for each student possible and natural (p. 30). Collins also states that the new technologies, in which the visual component is important, provide incentive for a shift from primarily verbal thought to thought that integrates the visual and the verbal (ibid.).

6. Assessment of Learning

For a time, the new technologies were often used to support or even consolidate existing diagnoses and assessments of learning. With the arrival of the latest technologies, we are witnessing a different phenomenon: in many cases, it is the technologies themselves that are dictating the new forms of assessment, which are more flexible and much more respectful of what learning is, or are used to implement them. This at least is what emerges from the research that could be done. The following two observations present a brief summary of the findings of this research.

THIRTEENTH OBSERVATION:

Assessment of learning

The new technologies foster a positive, close association of students with the assessment of their own learning, and uses and manages much more demanding assessment methods than is generally the case at present.

Reference points

a) The new technologies can be viewed as means for improving administration of the types of exams now used, and for storing and communicating their results (see Sheingold and Frederiksen, 1994, p. 130). In the field of learning assessment, however, these technologies can do much more; they are even indispensable to success of the wholesale reform launched a few years ago (see idem, pp. 111-112). In particular, they can serve five functions:

i) These technologies (in this instance, simulation software and various other computer tools that can represent, draw, analyze, interrelate, record, etc.) can "support students' work in extended, authentic learning activities" (see idem, p. 121).

ii) Given the potential of these technologies, students' work can easily take other forms that than of written text, or combine various forms, and be transmitted at any time, virtually in an instant, to examiners in another location. These technologies also allow a student's work to be reviewed as often as necessary, and allows the student as well as other people or authorized organizations, to keep a "copy" (see idem, pp. 121-124).

iii) These technologies can be used to build "libraries" or multimedia centers that bring together examples of students' work and instruments for interpretation. These locations may also have video editing and multimedia production equipment so teams of teachers can propose other approaches to assessment of student learning to their colleagues (see idem, pp. 121 and 124-126).

iv) These technologies can considerably expand the number of people involved in the development and critical review of assessment instruments consistent with the current requirements and capable of making an informed judgment on a student's portfolio, performance or skills demonstration work. These technologies make it possible to quickly exchange and discuss assessment instruments over distances, provide mutual assistance in the search for more appropriate instruments interpreted in the same manner everywhere, as well as carry out certain training and student consultation activities, or student selection, with teachers' assistance, of projects to be done or courses to be taken (see idem, pp. 121 and 126-128).

v) Finally, these technologies make possible the dissemination over computer networks of the best assessment instruments prepared by teachers and the best work produced by students (see idem, pp. 121 and 128-129).

b) "One of the greatest challenges of alternative forms of assessment, is keeping track of rich but extensive histories of student performance," asserts a major report abstract prepared for the US Congress (US Congress, Office of Technology Assessment, 1995, p. 73; see also Third Observation, b). In such cases, the technology may prove very useful. Thus, in part, an assessment based on the demonstration of performances, if supported by appropriate technology, "help teachers diagnose student strengths and weaknesses and adapt instruction accordingly, provide students with immediate feedback on their performance, let teachers record and score multiple aspects of competence, and maintain an efficient, detailed and continuous history of the student's progress" (idem, pp. 73-74).

c) The new technologies contribute to the transition from test-based learning assessment to project-based assessment also focusing on students' effort and progress (see Collins, 1991, p. 30; for some contextual factors, see also Fourth Observation, b).

FOURTEENTH OBSERVATION :

Diagnosing specific difficulties

By permitting rapid retracing of the various learning paths taken by a student, the new technologies facilitate detection by the teacher of this student's strong points as well as the specific difficulties the student encounters or prior incorrect or poorly assimilated learning.

Reference points

a) In schools where all teachers in a school or classroom have a computer and have access to their students' records and appropriate management software, each teacher can quickly determine whether a student is having learning difficulties with that teacher or other teachers, and take suitable action. In such cases, the technology serves as an "early warning system" and permits various types of intervention before the situation becomes too serious (see US Congress, Office of Technology Assessment, 1995, p. 73).

b) In Underwood, Cavendish and Lawson's (1996) assessment of an integrated learning system (see Third Observation, d) it was the diagnostic function of the system that produced the most visible if not the most pronounced effects on the teaching staff. One member of this staff who was very sceptical at the start of the experiment subsequently admitted that "it was now second nature to him to use the system's diagnostic reports and produce appropriate response to a child" (p. 957). In so doing, he noted for example that the reports produced by the integrated teaching system identified the words and groups of words with which a student was having difficulty. This information allowed him to devise a teaching plan related to this problem. This teacher also commented that the degree of accuracy of the system's diagnoses far exceeded what he would be capable of doing. "Thus," he explair [illegible] "Lydia has word skills problems but I was identifying the wrong skills -- the integrated learning system (ILS) sorted that for me and I could direct my efforts to solving the child's problems" (ibid.). The researchers reporting on their work noted that the diagnostic support provided by the technology used had allowed this teacher to act with competence. Furthermore, in the opinion of the school's administration, the thought process that use of this system had triggered had benefited other aspects of his teaching.

Many experienced teachers also confirm the benefits to be gained from the detailed diagnoses produced by the system. "Often," they state, "the detailed diagnostics are very useful, they often confirm my intuitions but do occasionally highlight problems or successes that I have not noted". The machine identifies a spurt in development before it becomes apparent in the classroom. Some children are reluctant to be seen as achievers but the machine prevents them from hiding their talents" (ibid.). In fact, the system detects the beginnings of success long before these become evident in the classroom. As a result, some students who do not like to show their ability to succeed are no longer able to hide their talents!

The diagnostic capabilities of the system also are relevant in dealing with the problem of students who learn and perform in the class in a manner that is satisfactory but not sufficient to result in substantial intellectual growth (Scardamalia, Bereiter & Lamon, 1994). The integrated learning system "can break this cozy pattern of behavior by stimulating a shift in both the teacher's and the child's perception of potential performance levels. ... In many cases children did not want to stand out from their peers but in other situations the child had developed a very comfortable non-stressful pattern of mediocre work that could be achieved with minimal effort" (Underwood, Cavendish and Lawson, 1996, p. 957).

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