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AUTHOR	Collis, Betty
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ABSTRACT

This report, which is not intended to be an exhaustive commentary, reviews and discusses educational applications of information technology (IT) at the elementary and secondary levels. Each of the six topical sections of the report discusses the instructional potential of information technology, realization of the potential, and predictions for the future. The first section addresses new resources, e.g., computer software, to support learning by individualizing instruction; bringing the outside world into the classroom; accessing vast amounts of information; processing complicated data; and providing microworlds, i.e., some kind of bounded universe, for student exploration. The second section approaches the expansion of computer and information sciences as a new curriculum situation, particularly at the secondary level, assesses its current success, and suggests other uses for its tools than are typically offered in schools. The next two sections evaluate changes in the organization of student interaction during learning experiences and additional changes in the role of the teacher. One such change may relate to the move from textbook-related class preparation to teachers creating their own instructional materials, using IT to design and create courseware. The fifth section discusses changes in the physical organization of educational situations within the traditional school building, and the sixth section describes changes in the macro-organization that IT has the potential to create. (21 references) (SD)

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Using Information Technology to Create New Educational Situations

Theme 4.1

by

Betty Collis

Department of Education
University of Twente
Postbus 217
7500 AE Enschede, The Netherlands
Telephone: 31-53-893642
EARN (BITNET): TOCOLLIS@HENUT5

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1. Introduction

1.1 Potential versus Realization

Information technology (IT) has the potential to create new educational situations in many different ways. To a limited extent, this potential is beginning to be realized[1] However, there are many factors that constrain this realization. Our task is to better identify which of these factors we can be most successful in manipulating so that the potential of IT to create new educational situations can be actualized. In this framework, we will discuss the potential of IT to create changes relative to:

1. Resources available to support learning,
2. Curriculum,
3. The organization of human interaction during the learning experience,
4. The teacher's role,
5. The physical environment of learning,
6. The macroorganization of learning.

1.2 Delimitations of the Paper

It is not intended that this one paper be a review of the literature relative to each of these areas. Hence, only a few major references are cited, rather than the network of references which would be necessary if the paper was to be a research summary. Neither does the paper attempt to offer an exhaustive commentary on areas of IT-related potential related to each of the above six points. It is intended instead that its major purpose be to stimulate discussion around some aspects of the overall situation. The paper will be based on research and practical experience, but the interpretations of this evidence will be those of the author. In particular, the speculations relative to the realizability of the potential of IT to create the various changes in educational situations predicted for it are offered as a stimulus for debate and deliberation at the Congress rather than as scientific conclusions.

Also, because of time limitations, this paper is focused on education at the elementary or secondary level. It may be that the use of IT to create new educational situations is a more vigourous growth area now in the context of higher education or of training in non-school settings than it is at the school-age level. However, because of the fundamental interest of countries throughout the world in improving the quality of basic education for its populace, we will limit our focus to the school-age group.

2. Creating New Resources to Support Learning

Clearly the microcomputer in itself is a "new resource" to support learning, a resource which in a remarkably short period of time has become familiar throughout the world. Beside the "newness" of the delivery medium itself, there are at least five categories of new resources to support learning that are directly related to IT and that have great potential for education. These categories relate to:

- individualizing instruction
- bringing the outside world into the classroom
- giving access to vast amounts of information
- processing complicated data

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1. We will define "realization" as the utilization of a resource in "wide-spread enough" fashion so that its benefits are being experienced by a variety of learners in naturally occurring situations (as opposed to experimental or special projects). Clearly this is not a very scientific definition: its essence is, stated more simply, "Do what extent are the things we predict could happen actually happening?"

-providing microworlds for exploration

As a general conclusion, I suggest that in each case, the potential of these resources to create new educational situations is strong, at least some aspects of the potential have been demonstrated in certain (often unrepresentative) situations, but the realization of the potential beyond these initial explorations has yet to occur. How do I justify this interpretation?

2.1 Individualing Instruction

2.1.1 Potential

Certainly a great deal has been hoped for with respect to the utilization of the computer as a tool to individualize instruction. We will consider later in this paper how this inidividualization might occur at a macroorganizational level. At this point however, we will focus on individualization within the traditional classroom environment. This may occur by using the computer to provide different routes and sequences of learning experiences to different learners, either within the same program or by facilitating the delivery of different sorts of learning experiences to students working in the same classroom with the same teacher.

2.1.2 Realizing the Potential

At one level, the potential of providing individualized instruction within software has, in its realization, turned out to be little more than simple branching to help, extra practice, or practice at a different level, based on the correspondence of student input with preexpected responses. More sophisticated examples of this level, such as the CBPA System in Israel and the CCC Materials in the United States are more sophisticated, not because they are more "intelligent" about how best to respond to different learner characteristics, but in that they offer large amounts of carefully sequenced material and have more features relating to automated control of the branching process than are present in smaller-scale software of the same type. However, recent careful analyses of student interactions with the Israeli system show that even the most sophisticated of the currently available individualized systems are significantly limited in the accuracy, relative to student needs, of the individualization they provide [2] The effectiveness of the individualization may be limited by technical decisions within the software--for example, with the Israeli system, in order to provide immediate feedback, an assessment of the student's input is made after each keystroke. The consequence of this is that keying errors are interpreted as conceptual errors and the student is branched accordingly. More significantly, however, the effectiveness of the individualization is limited by the still-primitive diagnostic facilities in the software.

In comparison with the CCC and the Israeli material, the majority of drill and tutorial programs available are even more restricted in terms of capability to interpret student needs (and thus to meaningfuly select sequences and content in order to individualize instruction.) Many types of common errors are typically not anticipated, and in the relatively few programs that have tried to make a meaningful diagnosis of student errors in order to improve the relevency of branching, the difficulty of the task has proved to be substantial.[3] Certainly, much work is going on, often under the perspectives of artificial intelligence or expert system research, but the output of this work is still small relative to its practical application. Probably the most successful applications have been in

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[2] See the Hativa references (1987, 1988)

[3] Martinak and his colleagues, (1987), for example, after an extensive analysis of students' conceptual problems in algebra, had only limited success (30% of errors matched) in developing software that could match student errors with an accurate diagnosis of student misconception, in order to provide an appropriate individualized response to the students.

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situations where there is a well defined but limited body of knowledge as well as inference rules relating to that knowledge. With the exception of Brown and Burton's early (1977) work on "buggy rules" for diagnosis of subtraction errors, the most productive of these applications have been in specialized areas at the professional or at least the postsecondary level [4]

2.1.3 Prediction

Why has the capacity of software to individualize instruction as yet realized so little of the potential predicted for it? My own prediction, admittedly one with which many will disagree, is that this sort of realization is not going to occur, at least in the foreseeable future, on any level significant enough to compensate the effort and time that will be necessary to make substantially more progress than we already have.

I do predict some valuable developments. I think work focussed on the better anticipation of common errors or misconceptions in a subject domain should continue (regardless of IT, by the way), and the results of this sort of work should continue to strengthen the learning involved with computer use in content-specific situations even as it strengthens our more general understanding of the learning process. Also, I think content-specific programs may come to more routinely offer a wider variety of help options than are typically now available to the learner, in that we know that different learners prefer and d . better with different types of learning aids and approaches.

However, beyond this, I am sceptical about the potential of computers to intelligently individualize instruction, because for such potential to be realized, we must know much more about the process of thinking and learning than we now do. Given the difficulty with which we have made the limited progress that we have with respect to understanding the learning process,[5] I personally predict only little realization of the potential of the computer relative to its delivery of meaningful, individualized learning experiences to the learner--at least until we know much more about the process of thinking.[6]

There is another problem that I see as significantly limiting the realization of the potential of the computer to promote inidividualized instruction, and this problem is independent of the limitations in our understanding of how students learn. As long as school organizational schemes remain the same, it is very difficult to accommodate differential acceleration among students. If learners are able to move through material at their own rates, a great discrepancy in current student level of achievement can soon occur. Then what? Experiences with programmed learning showed us that it becomes more and more difficult for teacher-reenforced, socially embedded learning activities to occur the more that students in a classroom are widely spread in the content they are studying. More and more instruction must then become individualized, a situation which becomes increasingly difficult to manage and, possibly, looses some important aspects of learning relative to interpersonal exchanges. The most obvious response to this is that traditional organizational patterns for education should be changed so that individualized learning can better occur. We will discuss this later in this paper; however, my opinion is that certain aspects of teacher-led learning situations where students learn from each other and are aided in their learning by direct interactions with the teacher are a desirable part of learning--the overall goal of individualized instruction is limited by this.

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4 See Dede, (1986) for a comprehensive summary.

5 It may be that the major realizations we have acquired are that the process is enormously complex and that it varies from individual to individual as well as within the individual, depending on situational variables.

6 I recognize that it may be the experiences we are acquiring with respect to our attempts at individualized instruction with computers that we will directly contribute to this better understanding.

Thus, in summary, my predictions of the extent to which IT use can individualize instruction are conservative, for theoretical and practical reasons that I do not believe are much amenable to manipulation.

2.2 Bringing the Outside World into the Classroom

2.2.1 Potential

With the use of modems, an expanded range of educational experiences are becoming available in the traditional classroom. These relate either to direct communication between students, or to access to remote information sources. The second approach will be discussed in the next section of this paper. Direct communication between students in different schools, areas, or countries is an area of current intensive interest. The International Council for Computers in Education, (ICCE) for example, is sponsoring an international symposium in August 1989 focused entirely on this topic.[7] Projects are in place throughout the world in which students in one locale communicate with students in another, either to learn more about each other's culture, as an experience in writing for a specific audience or for a specific purpose (often developing a joint "newspaper"), or to exchange scientific data relative to a shared topic of exploration, such as climate or acid rain[8].

What can be gained from this experience that cannot be had from sending information through the regular mail, or by using the telephone? The major benefits are immediacy in comparison with the regular mail, and manipulatability of information compared to the telephone. Students can share in the preparation of material for telecommunicating in a way which is hard to envisage with a telephone conversation. Also, because of differences in time zones and the costs of long-distance telephoning, the use of the telephone as a communication tool in the school setting has never seemed feasible. However, telecommunications is seen as having the potential of being a significant motivator for cooperative student projects.

2.2.2 Realization

Although a noteworthy amount of telecommunications activity is currently occurring in school settings, the actual amount of sustained activity beyond initial exploration is still very small. The most obvious constraints are financial and physical--it is generally complicated and costly to support a telecommunications linkage. In addition, the maintainence of these linkages and the technical support that teachers need to manipulate the system are also costly and logistically difficult. Even among projects that are part of centrally organized initiatives and where set-up, maintainence, and support are supplied, the general pattern of utilization of these linkages is one of much less than would seem warranted by the potential . Technical problems continue, but more often it is pedagogical relevance that is not found, so that the experience becomes a one-time, interesting activity but one without enough substance to have much educational value. Also, management problems are a major constraint on the utilization of telecommunications in education. For example, how does the teacher organize access to the system, so that more than a few students can benefit from whatever it is that is gained by interacting with the telecommunications? How does the teacher evaluate the benefit to students of these types of activities? How can we justify the cost relative to the gains? Are all the students in a class involved, or only a few? If the latter, what are the rest doing while the few are getting the telecommunicating opportunity?

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7 Information about this meeting, called the International Symposium for Telecommunications in Education, can be obtained from Mr. B. Feinstein, Ministry of Education, Rehovat, Israel.

8 One of the most ambitious of these projects, is **Kidnet**, cosponsored by the National Geographic Society in the United States and involving over 200 schools in six countries (as of April 1988).

2.2.3 Prediction

I predict more hope for overcoming these problems than I did for overcoming the problems of building effective individualized instruction within computer-managed environments. Problems of cost and access, I predict. will fade as natural market pressures make telecommunications more and more ordinary. The example of the telephone shows us that people can standardize and cooperate to create a common communications environment .

However, one thing may thwart the continued growth of computer-mediated telecommunications, as we now know it. That is the quick rise in prominence of telefax use. For many types of information exchanges, telefax transmission is more efficient and even more effective than file transmission through telecommunications, particularly for source documents. My prediction here is less confident, but I think we will soon see the appearance of ideas for the educational uses of telefaxing, and that many of the exchanges we are motivated to do with computers will be handled more conveniently by fax. This will result in a lack of a critical mass of computers being used for telecommunications in the classroom, which may, in turn, prevent the substantial improvements on access and economies of scale that are necessary if this kind of use is going to have any impact.

2.2.4 Qualification on the Prediction

My predictions relative to educational focus and management of the telecommunication experience are based on the assumptions that we can find, document, and disseminate good ideas about telecommunications use in schools. These good ideas have to include management strategies for teachers. I am confident such "good ideas" will continue to be found, and that the main issue is therefore one of dissemination of instructional strategies. This, I think, we can do. We must begin by collecting information about existing practice as well as about existing problems. ICCE has adopted this as a priority service. Without attention to the implementation of telecommunications, experience confirms that its educational potential will just not be realized. It can, in fact, often become a negative experience because of the frustration and lost time involved relative to the little apparent educational gain.

2.3 Giving Access to Vast Amounts of Information

2.3.1 Potential

Telecommunications can also be used to bring access to vast amounts of information. Through a subscription to one of the many public information services, students and teachers can access a range of newspapers, magazines, and other source materials, more than could be available in physical form in any one school. Some of these commercial informational services offer special opportunities for student and school usage. An example of this is The Times Educational Network, operating out of the UK. The vision of the teacher as a guide to the locating of information rather than as the disseminator of information (a point we will discuss later in this paper) is dependent on access to large amounts of pertinent information. Utilization of online informational data bases would seem therefore to have strong potential in terms of being a change agent in educational situations, at least at the secondary level where students study world affairs and contemporary issues.

2.3.2 Realization

But this is another area where potential is not, as yet, being realized. The same problems that constrain the use of telecommunications for communications between students can also constrain its use for information accessing. The pedagogical relevance of accessing informational data bases is easier to describe than may be case in using telecommunications for direct communication between students, and the power of accessing significant amounts of current information easier to accept in terms of being educationally significant. Despite this, very few students have yet had any exposure to this sort of opportunity and probably only a very small subset of those who have make use of the opportunity in more than a cursory. limited way.[9] The technical and financial aspects of online searching are still a major constraint, although often more in impression than in fact, as the cost of using an information service in a judicious but productive and regular way can be can be considerably less than the cost of buying an additional computer.[10]

I think the major constraint here is one of orientation--we are not yet oriented toward educational goals relating to the location and synthesis of information, despite the occasional "research project" students are given. We continue to test students on predetermined content. We really do not know what to do with a vast quantity of information; we cannot think of useful questions. Also, we do not know how to manage the experience--how can students have equal opportunities to make inquiries of the information sources?

2.3.3 Predictions

Here again I still have optimism about predicting some sort of realization of potential. I think the need for information accessing skills is going to escalate so much in society that the educational community will agree that there is a need for systematic experiences with this type of access throughout school. Locations with constrained local resources will be able to access the same range of information as can more advantaged areas, which could be a real breakthrough in attempts to equalize opportunity in education. So I predict there will be a social press for development of these sorts of experiences in schools. Teachers who only refer to the textbook or to their own accumulated information on a topic will gradually be outnumbered by teachers with skills to utilize more, and more varied, resources. This does not, of course, imply that teaching and learning will necessarily be better--having access to information is only a first step Different approaches in teacher training and in student assessment criteria will have to occur, and classroom management strategies will still have to be developed and modelled. However, these are manipulatable variables. Teacher disposition toward this sort of experience may be less easy to manipulate, despite training activities, in that the conceptual and management challenges will be significant.

2.4 Processing Complicated Data

2.4.1 Potential

IT tools can be used to perform tedious or complicated data manipulations that would otherwise constrain student participation in various educational experiences. For example, in the science classroom, data-capturing peripherals can be readily affixed to even simple computers to allow the capture and manipulation of types of data that students might not otherwise be able to experiment with or use. Work in this area of the application of MBL's (microcomputer-based laboratories) is extremely promising and, I predict, can allow a real change in the science laboratory situation in schools.[11] More extensive and realistic manipulation of variables can take place, with more time available for student speculation about hypotheses, as less time has to be spent on mechanical tasks, such as graphing of data or recording streams of data.

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9 See Martinez and Mead (1988) and Kass, Kieren, Collis, and Thernen (1987) for results of two national surveys in North America.

10 Riedl (1986) calculated the cost of 40 students and three teachers making extensive use of an online informational service from their school in Alaska to be $320 US for an entire school year.

11 See the Nachmias and Linn reference for a summary.

Similarly in the senior mathematics classroom, IT devices can be used as tools to enable learning situations that might not otherwise occur. Monte Carlo simulations to develop concepts of inferential statistics, the use of graphing tools to investigate characteristics of complex functional expressions, the use of spreadsheets to develop skills in projecting and manipulating trends in quantitative data--these all relate to important aspects of mathematics which are not often included in school syllabi. possibily because of the conceptual difficulty of dealing with these topics if support calculations could not be done in an incidental way relative to the actual concept formation.

Qualitative data can also be complicated. We have already discussed the difficulties inherent in locating, synthesizing, and projecting trends from information in large informational data bases and how technology can be used to overcome these difficulties in the social science classroom. In mother-tongue classes, the contribution to the development of the writing process through the electronic manipulation of text has been extensively discussed and researched.

2.4.2 Realization

All these promising new educational systems involving IT share one frustrating characteristic--all are still relatively little utilized in actual practice. National surveys in the USA and Canada, for example, yield almost identical data on this point[12]--despite the near-universal presence of computers in secondary schools and the exposure of most students in those countries to some sort of introductory computer-use course, less than 14% of the over 27,000 students in the surveys had ever made use of computers, in any way, in their science and social science courses, and less than 22% in their mathematics courses. Word processing in support of writing is also little used (only 16% of the respondents indicated they had ever experienced this) although more than half of the respondents had had training in word processing techniques in their introductory IT courses.

2.4.3 Constraints on Realization

Why is realization proceeding so slowly? It is convenient, and true to a certain point, to say there is not adequate hardware, software, and teacher training. But even in situations with reasonable provisions of these support resources, such as in North America, computer use in schools is dominated by IT-specific courses rather than by integration of IT in a way that creates new educational situations in other subject areas. I think the problems here are more subtle, and more difficult. We haven't succeeded yet in demonstrating to teachers that there are real educational needs that IT tools can help them address more effectively than they could using other tools. It is my perception that IT use in conjunction with regular instruction is still too often perceived as more of a frill than an important opportunity. I also think the management and organizational aspects of integrating IT tools into instructional delivery outside of the informatics course create a major constraint on the realization of the potential of the tools. We will discuss these aspects more later in this paper. It is, however, my opinion that the constraints related to management and implementation are more serious than may be acknowledged and the manipulation of them is a particularly important aspect of improving the realization of the potential of informatics to create new educational situations.[13]

12 See Footnote 9

13 See Collis, (1988b), for a lengthy discussion.

2.5 Providing Microworlds for Exploration

2.5.1 Potential

The term "microworld" came to widespread attention in the context of Logo experiences.[14] . However, it can be used more broadly, to describe any situation where IT allows the student to explore and manipulate some kind of bounded universe. The use of simulation programs can also fit this definition. In a sense, working with a tool such as a spreadsheet can also be seen as a microworld-type experience. Beside the relevance they may have with respect to certain learning domains, an additional goal of many microworld explorations is to enhance students' higher-level thinking skills. This kind of enhancment is sometimes predicted in terms of gains in problem solving skills, or planning skills, or in terms of some other aspect of cognitive activity.

2.5.2 Realization

Much research has occurred to investigate various types of learning gains that might be associated with microworld explorations. The general outcome of this research is a deeper appreciation of the complexity of skill development in these sorts of environments. Beyond this, the outcomes are not clear.[15] Many factors influence any results that do occur, results are inconsistent across studies, management and organization of the experiences is challenging--often enough to prevent the experiences from being used for more than a limited, exploratory time. Some generalizations, however, are emerging--perhaps most strongly that student explorations with microworlds result in more demonstrable learning gains when student exploration is guided by the teacher and integrated into a complete instructional experience than when the student works more independently. As a corollary to this, another trend emerges consistently--except for very unusual students, most students seem to lack the motivation or vision to explore microworld environments to any depth without effective teacher guidance.

2.5.3 Prediction

How do these observations relate to critical, manipulable variables? The point about teacher guidance gives us a clear message--focus on helping the teacher visualize, prepare, and manage educational activities that include microworld exploration but that guide students toward certain goals. This does not have to constrain the emergence of other outcomes from such explorations. The opinion about student motivation is more controversial. I believe that, despite an ongoing theme in educational theory relating to the idea of the student being an architect of his own learning if he is only given the appropriate tools, most students are not going to be intrinsically motivated to deal with strenous intellectual challenges or be able to extract principles and concepts from their explorations. This, in fact, may be a critical variable that is limited in its manipulability--if the new educational situations created by IT assume a new type of learner and teacher, then there may be continual frustrations in realizing the potential of these situations, at least in the foreseeable future.

3. Informatics as a New Curriculum Situation

We have examined so far the potential of creating new educational situations through the use of IT-related resources as learning tools. Let us now turn our focus more broadly to the potential of IT to influence larger-scale aspects of education. The first of these is curriculum.

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14 Papert (1980), of course, brought the word and idea to broad public attention.

15 See Govier, (1988), for an excellent summary of Logo research in the UK.

3.1 Potential and Realization

In contrast to the limited realization of the potential of IT in terms of creating new educational situations in traditional curriculum areas, there is no doubt that IT has been associated with one new type of educational situation which has rapidly become widespread throughout the world. This is a course, or at least a compulsory unit of instruction, in informatics (called by various names in different places). In many countries, this type of experience has been mandated nationally; in countries where this has not happened at the national level it is nonetheless common to find some kind of local initiative specifiying this type of new educational situation. These experiences are common at both the introductory level and the more-specialized level. Frequently they include programming although the introductory courses now usually include some experiences with applications software. The rapid acceptance, throughout the world, of a new content area in schools, one which requires relatively heavy capital investment and one for which there is no installed base of trained teachers, is remarkable.

3.2 Constraints on Realization

Beside noting that the courses exist, it is difficult to comment on their value. The initial motivation for many of the courses was better employability for students in a future technologically-dominated society. Careful analyses of projected employment needs over the next decades[16] plus a logical analysis of the contribution of the typical school informatics course to subsequent employability requirements has made this motivation for informatics courses less credible. The contribution of school-level informatics courses to subsequent success in profession training with respect to informatics is also hard to clarify. In general, because of the variation in the content and quality of secondary school informatics experiences, universities will begin computer science instruction in a way that does not require the student to have had preliminary courses in secondary school. The uncertain contribution of these courses to the development of better higher-level thinking skills can be seen from an examination of the extensive research in this area.[17] .

There is not even much data to help us evaluate what students are actually learning in school-level informatics courses. Sometimes syllabi are compared for subsequent analysis, but student learning is not much synthesized from place to place or country to country. Some data are available. The Martinez and Mead survey (1988) of over 24,000 U.S. students determined that the majority of these students (67%) had had some kind of informatics study in school, virtually all came from schools with computer resources, and most have "some familiarity with computers, for example, they can identify a keyboard, disk drive, and printer. but with the exception of word processing, only a small fraction were able to answer questions about the most important computer applications" (p. 29).

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16 See Levin and Rumberger (1985)

17 See Blume (1984) and Land & Turner (1985) for reviews.

3.3 Predictions

Through the appearance of new courses in school, IT has definitely caused a change in the educational situation, certainly in secondary schools. In my opinion, however, there is little reason to think that the money and effort that has gone into the establishment and maintainence of many of these courses is paying off. I would like to go even further and call for a cost-benefit assessment of such courses; relative both to alternative uses of the same amount of money, perhaps for the integration of various types of computer use into curriculum-related instruction (for example, telecommunications for information access and science data-capturing peripherals for experimentation enhancement); or relative to other, non-IT uses. Again, in my opinion, the impact of informatics courses on the overall educational situation in schools may be both too much and too little, too much if the majority of computer-related resources is focused on these courses, and too little if the uses of IT which may be encountered in those courses are not reinforced by application in "real" situations throughout the school and the students' school experiences. It has been argued that a reasonable level of "informatics competency" can be developed through judicious use of IT tools in various appropriate ways in the context of regular curriculum instruction.[17] I am not suggesting that an informatics awareness course and some sort of systematic instruction in IT tool usage skills be removed from school experiences; on the contrary, I am suggesting increased awareness, but through more realistic and cyclical use of IT tools than typically happens now when, for many students, a single exposure in an informatics course is all the contact they have with school IT resources.

4. Changes in The Organization of Human Interaction During Learning Experiences

4.1 Student-Student Interaction

4.1.1 Potential and Realization

Occasionally a rather grim image is projected relative to some futuristic learning situation. In this image, a small child sits alone with a computer, isolated from human interaction. Another grim image is that of the computer-obsessed student, forsaking normal human interaction in order to work with his computer. Although some examples of the latter sort of absorption do occur, IT use is more generally becoming associated with some encouraging trends in the social organization of learning. Although the majority of software packages are designed around the assumption of a single user interacting for some period of time with a computer (an assumption that shows how many software designers fail to anticipate the context that will constrain use of their packages in the real-world classroom), the practical reality, of a limited number of machines in the school environment compared to the number of students wanting to use the machines, has fostered the development of group work, or at least paired-student work, with IT tools.

Sometimes the group organization is deliberate rather than a response to situational constraints. Some senior-level informatics courses are trying to mirror "real-world" experiences in software development by structuring student experiences and assignments around group work. Some telecommunications experiences are developed around the idea of group interaction for the construction of responses to messages. The idea of writing as a social activity, made possible by word processing and desktop publishing facilities is also gaining recognition. Group work in the context of learning programming has been perhaps the most extensively researched aspect relating to social organization of IT-related experiences. Results have been positive.[19] Student cooperation during the use of simulation software is

18 See Lockheed and Mandinach (1986) and Collis (1988a)
19 Webb (1985) writes extensively on this.
20. See Johnson, Johnson, and Stanne (1986) for an example

frequently encouraged and again has been shown to be associated with better learning outcomes than independent interaction with the same software[20].

4.1.2 Constraints on Potential

Certainly, group work existed before an IT-context. I do not think we can say that IT "creates" any new educational situation in terms of student-student social interaction. However, it does seem that certain types of IT use can naturally promote student-student interaction in ways which would probably not occur with traditional resources, if the teacher allows it. Given this promising research, why isn't student-student interaction encouraged more as part of IT-related experiences? I think one reason relates to software; as mentioned earlier, most software is built around a single-user model. Two students working together, for example, often have to be called by a common name when getting feedback from the program, and virtually never is prompting given with the purpose of encouraging students to take turns at responding. Also, still, most software is drill-and-practice in approach, an unnatural environment for multiple users unless both are at a similar ability level.

Another reason relates to the difficulty of organizing group work in the classroom. If students are not used to group work, some may dominate the group or the group may not be comfortable or efficient at apportioning responsibility. Assessing group work is also difficult in terms of the need to eventually assign individual marks to students. Finally, group work may be outside the teacher's range of preferred classroom organizations; certainly group work is associated with a level of movement and noise in the classroom which does not always remain under control, nor do all students work productively during group work sessions. Thus, in my opinion, teacher-comfort level relative to levels of control and management in the classroom is a critical constraint on the types of IT experiences that will occur in his classroom. I am not sure how successfully we can manipulate this.

4.2 Changes in Teacher-Student Interaction

4.2.1 Potential

It is frequently stated that IT tools create the possibility of new or newly-emphasized forms of student-teacher interaction (in the next section of this paper we discuss in a more general way potential changes in the role of the teacher). One of the most frequent comments is that IT gives the student tools to "be in control of" his own learning, and that therefore the teacher serves as a reference person, relative to strategies for locating information, or a facilitator, relative to helping the student realize his own decisions about learning.[21] A less radical view sees IT, usually in the context of computer-managed drill programs, keeping track of "routine" student activity in some sort of predictable situation, such as drill work in arithmetic, freeing the teacher to interact more closely with students over more stimulating or demanding topics.

4.2.2 Predictions

I am sceptical about both of these premises, both in terms of their value conceptually and in terms of their realizability.

My conceptual objectives to the first vision relate to the point I have already made--that I do not think the great majority of students can or will organize their own learning activities in a far-sighted way on more than a short-term basis. Mathematics or science or history or chemistry, for example, as rich and dense conceptual areas, cannot be effectively anticipated by the student so that he can

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21. See Solomon (1986) as an example
22. See the US Congress, Office of Technology Assessment report (1988)

chose appropriate learning directions over more than a short time, even assuming he is motivated to challenge himself. I am not suggesting that students not be given some control over their learning options; however, I believe in general that the student is not able to create the options in order to chose among them unless he already has some sophistication in the content area and in monitoring his own behaviour. We have so much evidence about the importance of the teacher in appropriately sequencing instruction for students and of the importance of sequence in many curriculum areas, that I think it is romantic (and, in my opinion, undesirable) rather than realistic to project a radical change in the nature of teacher-student interactions.

My objections to the second "vision" are based on experience--so far, IT use in the classroom is typically associated with more work for teachers, rather than with more freed time for higher-level activities[22] Also it appears that much of the extra time demands on teachers relate to low-level organizational matters associated with technological management, rather than on enriched higher-level contacts with students. Another issue is that teachers frequently lack the time to interpret information on student activity as collected by computer-management systems during student use of drill programs. The fact that these printouts often give little information beyond "number tried" and "number correct " adds to the unlikelihood that any meaningful managment of learning is being done for the teacher.

I do believe there is at least one aspect of student-teacher interaction which IT experiences can promote which is of potentially high significance. The teacher as an IT user, especially as a new IT user, is inevitably going to be faced with challenges in the classrom, ranging from the trivial troubleshooting of aberrent equipment to much more challenging problems involved with understanding facets of a new software package or hardware system. I believe that students often learn from observing the modelling that they see in their teachers' behaviours. Students can watch the teacher as a learner, relative to IT use, and see him as a learner that can sometimes be taught by the students. There can be a palpable change in the atmosphere between teacher and students when the students can share a legitimate problem solving experience with the teacher, not just react to one contrived for them by the teacher. I believe the teacher can set a particularly strong example of viewing problems not as failure experiences but as interesting challenges for which a variety of lines of investigation may be appropriate. A tendency toward more and more "user-friendly" software may, ironically, reduce the likelihood of this sort of shared learning experience. Also, teachers have to be willing to grapple with their own lack of knowledge in view of their students and be comfortable with letting students see them as sometimes unsuccessful. This sort of willingness may not be easy to develop.

5. Changes in the Teacher's Role

5.1 Potential

Many of the comments that can be made relative to the potential of IT with respect to changes in the teacher's role have already been discussed in the context of teacher-student interaction. However, a few other observations are pertinent. One relates to the type of learning materials and experiences that the teacher organizes for his students. The most common preparation pattern for many teachers seems to be textbook-related. Teachers do make their own instructional materials, generally in print form although often in the form of extra visual aids. Many software packages are equipped with facilities through which teachers can modify data sets in the software and thus personalize computer-related learning experiences for their students. The extreme form of this relates to complete authoring environments for teachers, where the teachers can ostensibly design and create their own software.

5.2 Realization

How much is this potential for software development or modification being realized by teachers? I do not have good data on this, but my impression is--very little. If this perception is accurate, then what factors are impeding the realization?

One response is to look for more sophisticated possibilites; perhaps teachers are not now bothering to spend time adapting software if in fact they can only make highly constrained changes? Perhaps tools that allow teachers to create lesson materials through assessing multi-media data bases will make a critical difference? Another response is to search for easier-to-use authoring tools, with improvements in user-friendly interfaces.

5.3 Prediction

My prediction here is that efforts such as these will not result in increased realization of authoring or adaptation potential in any widespread way--unless other changes occur first. These are changes that relate to the much more fundamental issue of teachers coming to believe that IT-related use relative to important educational problems can make a significant contribution. Until this commitment is more widespread, I do not predict much increased willingness to spend time on modification of materials for IT use.

In summary then, relating to both this section and Section 4.2, I differ from many in that I do not predict IT use in educational settings will create a fundamentally new role for the teacher. I believe the things that are most important now about the process of being a good teacher will remain just as important. I think the teacher will be faced with a wider spectrum of things to know about and do, and a wider range of creative opportunities, because of IT, but in general I believe that the important aspects of being a good teacher--planning, assessing, reinforcing, motivating, interpreting, interacting, caring--will remain as important as ever.

6. Changes in the Physical Organization of Educational Situations Within the School

6.1 Potential and Realization

In Section 7 we will discuss changes in the macroorganization of schooling that IT has the potential to facilitate. In this section, we will assume the traditional school building and organization.

IT has already made a visible change in the physical organization of at least one room of schools in many locations throughout the world. Having a computer laboratory is no longer unusual in many countries, and computer rooms are also found in at least some elementary schools. In many schools, computers are locally networked (LANs). Stand-alone computers are also relatively common in schools, although the laboratory is seen as highly desirable for informatics instruction.

Although this rapid infusion of costly new equipment along with the challenge of finding a room in the school that can be converted into a computer laboratory is significant in itself, there are many ways that the physical organization of the school could be further changed because of IT. In many secondary schools, there is more than one computer laboratory. Often an additional laboratory is dedicated to instruction related to data processing and office skills. Laboratories for CAD-CAM installations or for other technical training situations are also becoming widespread, in more affluent societies. The idea of having smaller clusters of computers, particularly to service students' word processing requirements, is beginning to be realized. Some school libraries are being reorganized around various applications of IT, ranging from circulation and card catalogue utilization to on-line linkages with external information sources.

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Predictions about the potential of changes in the physical organization of the school can involve even more than the appearance of new rooms of equipment. As the library situation suggests, there is a potential to substantially reorganize theworking environment of the student. In some well-networked schools, a student can log on to the computer system at any one of many terminals located throughout the school and access his own work[23] . However, these networks still often cause technical difficulties and do require ongoing technical support.

Some see the potential extension of local area networks to be a situation where every student has his own portable computer and can access the central resources of the school through any workplace of his choice. Instead of organizing the school around the notion of classrooms with desks aligned to face the teacher and the chalkboard, both centrally positioned at the front of the room, the school building may radically change in its interior. Access to a printer will be more critical than proximity to a chalkboard. Since teachers, in this sort of environment, will be "resource guides" more than they will be "front-of-class lecturers", the traditional classroom may more and more be reorganized to look like a resource centre.

6.2 Reflections on Current Realization Relative to Laboratories

For certain teaching situations the computer laboratory is both convenient and desirable, such as for teaching groups of informatics students. However, a number of problems have become associated with the computer laboratory organization. These problems relate to access, instructional integration, and atmosphere.

6.2.1 Access

Computer laboratories often become bottlenecks to access to school computers for both staff and students. Because informatics courses are popular, and sometimes compulsory, these courses themselves place heavy demands on the scheduling of computer laboratories. Consequently, it can become difficult for non-informatics teachers or students to have access to the computers. As a result, a pattern can emerge in which the few informatics teachers become virtually the only users of school resources and the computer laboratories are seen as the their domain. This has an impact on both instructional integration and atmosphere.

6.2.2 Instructional Integration

It is, of course, possible to manage less informatics-domination of the computer laboratory through centralized scheduling or through having more laboratories. However, a potentially more serious problem remains. For the non-informatics teacher who wishes on occasion to integrate some type of computer-use experience into his larger instructional plan, the physical process of relocating his students into the lab for the experience is often disruptive to lesson flow. This is especially so if the experience is of relatively short duration, although still of instructional value, as may be the case with the desire to access an online informational data base, for example, or to demonstrate a certain functional relationship in mathematics. Sometimes, for instructional integration, the use of computers fixed in a central laboratory is impossible, as may be the case in wanting to capture some data during chemistry experiments, as an example.

With younger students in elementary school situations where a laboratory may have a smaller number of computers, the teacher faces additional problems--how can some students be in the laboratory with the computers while others remain in the classroom? How can the teacher work with both sets of students at the same time? Is the solution that the students in the computer room are unsupervised,

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23 The province of Ontario in Canada has extensive experience with networked schools.

under the assumption that they can work independently with the computers? Probably this in turn assumes that they will be doing a sort of computer work, such as drill, which can (not should) be done in isolation. However, both conceptual and technical difficulties still occur, leaving young children alone in a computer room without support. To realize potential, schools need at least an aid in the computer room to deal with technical questions, but this does not compensate for the missed opportunities for interaction between the teacher and students. To maximize instructional integration of copmuter use, it would seem desirable to have a number of computer laboratories, extra teachers, and stand-alone computers for specific classroom uses. To realize this kind of potential requires more money than is available in virtually any school jurisdiction, unless a "special project" is mounted with substantial outside support.

6.2.3 Atmosphere

Another consequence of the informatics domination of school computer facilities is the situation that not only a subset of students and teachers, but also a certain type of students and teachers, often become associated with the computer laboratories, in secondary schools at least. In many places, this group is characterized by male students taking (or expecting to take) higher-level mathematics courses. The strong correlation between this and the fact that fewer females than males make use of school computers or take elective informatics courses does not of course imply causation, but it does support the observation that in many places the computer laboratory develops a characteristic atmosphere which does not seem to encourage usage for certain groups of teachers and students. One response to this is to encourage more widespread instructional integration, but as we noted above, until resource provisions are considerably larger, laboratory placement of computers can thwart attempts at this type of organization.

6.3 Predictions

I do predict we will see more and more computer laboratories in schools. Despite their problems, they make a more natural management unit than is the case with computers dispersed throughout the school and are the most logical teaching environment for informatics instruction as well as other specialist courses, such as office skills training. Bottleneck problems will be addressed by buying more computers and setting up more labs, even though this may not do what is needed for problems of instructional integration in the regular classroom environment. Local area networks will also continue to grow in popularity, not so much for pedagogical reasons but because of the problems of having multiple copies of software to service multiple machines in a school and of having access to printers. With the rapid spread of technological advances in society, I think it is quite likely that this sort of physical change will continue to occur in schools.

7. Changes in the Macroorganization of Schools

7.1 Potential and Current Realization

I believe there are two basic frameworks for potential changes in the macroorganization of schooling, given large-scale IT resources. One framework is that "the school" can be brought to students who would not be able to access it otherwise. We can see examples of this in the use of computers and telecommunications, as well as other technologies, for the delivery of instruction to students living in remote areas in Australia and Canada, among other places. Distance education augmented by IT allows interaction and multi-media provision of resources in ways not possible with traditional print-and mail-based distance education. Courses requiring specialist teachers can be delivered to students in small, rural schools. The potential impact of this on inequities in educational opportunities based on geography is highly significant.

The second framework relates not to bringing the school to the student, but instead to giving the student access to enough resources so that "the school" is no longer necessary. A number of visionary predictions about the potential of IT to facilitate this sort of "liberating" self-sufficiency have been made. Some are less radical in that they see the student still going, on occasion, to a "school" for some sort of interaction with a teacher or other students; others predict the dissolution of schools, and of the teaching profession, as a natural outcome of IT realization. There is no experience yet to cite with respect to this sort of potential.

7.2 Predictions

I predict IT-mediated distance education, delivering educational opportunities to students for whom the opportunities would not be otherwise possible, is an important growth area for IT. I think realization of potential to some extent will occur because the need is strong and clear. Technical problems abound, and a costly infrastructure is needed to handle this sort of realization. Portability of materials must also be considered, not only from the technical perspective but also from a cultural perspective. This involves not only the student's community-related culture, but also the pedagogical culture with which the student is comfortable. We have enough experience to know that all of these are significant constraints on realization, but constraints which can, I predict, be dealt with when the need and will for IT-supported compensatory education is strong.

I have the opposite prediction about the "school will fade away" scenario. I believe the need for school organization; for teachers as instructional leaders, not just reference guides; for human-to-human support, interaction, and motivation will all continue. Given the many constraints on realization I have discussed throughout this paper, I am confident in my final prediction: that many elements of traditional school organization will, and should, remain regardless of IT's potential.

8. Summary

In this essay I have looked at the potential of IT in basic and secondary education from a variety of perspectives. I have also commented on constraints to the realization of the potential and given my opinions as to the manipulatibility of those constraints. During the presentation at the Congress I will summarize my predictions and suggest which ones I think are most amenable to our efforts at manipulation--and which ones I think will not be realized, at least in the foreseeable future.

I am sure that my opinions will be different from those of others and in some cases will be seen as provocative. I welcome the debate about them, but of course no "answer" will be found. However, I think such a debate can have at least two contributions: first, the identification of constraints to realization that are more amenable to manipulation in order to better target our collective efforts with regard to advancing the impact of IT in education; and second, the more fundamental consideration about educational assumptions that can come out of such a debate. Perhaps one of the major contributions of IT to educational change lies here--in the fact that throughout the world the potential of information technology continues to be a tremendous catalyst for such debate and educational examination.

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