Chapter 4

Information Technology and Children
From a Classroom Perspective

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Information technology (IT), primarily involving the application of computers in the educational setting, is perceived by educators and the public in countries throughout the world as capable of having a significant effect on the developing child. The study of this effect—what mediates it and how it may be channeled to the best advantage of the child—is a topic of major interest to researchers, teachers, and educational decision makers throughout the world.

Despite this extensive interest in the impact of computers in education, it remains difficult to draw conclusions from the experiences that are occurring. This is partly because the IT field is continually changing in its characteristics, but more importantly it is because "the effect" of computer use cannot be expressed in a straightforward fashion, but instead must be considered in the context of the complicated network of variables in which the use is embedded (Collis, 1988; McGee, 1987; Salomon, 1990). These variables include characteristics of the computer use itself, such as software types and design aspects, as well as hardware variations. They also include variables related to various characteristics of the students and teachers involved, and of teacher decision making, including how effectively the teacher integrates computer use into a meaningful learning experience for the child. The social interaction between student and student and between teacher and student also influences the impact of computer use in school (Feldman, 1989; Tharp, 1989). In addition, school, regional, and national culture also are part of the system of influences, as culture in its various manifestations embeds and shapes the system and the subsequent result of computer use (Peled, Peled, & Alexander, 1989).
Despite these challenges, there is a consensus that research into the impact of computer use on children's cognitive functioning must be done, but done in a way that is sensitive to the system of variables that shape and are shaped by it. In response to this challenge, UNESCO, the Bulgarian Ministry of Science and Higher Education, the Bulgarian National Neuroscience and Behavior Research Program and other sponsors representing researchers from 19 countries collaborated in a major cross-cultural research project, called Information Technology in Education and Children (ITEC). The ITEC Project formally began in May 1988 at an international meeting in Bulgaria initiated by UNESCO and finished its analysis and reporting in 1992. Sixteen countries were actively involved throughout the study as settings for school observations.

In this chapter, we briefly describe this project, including its conceptual, methodological, and organizational evolution. We describe the data-gathering and analysis procedures in the study and summarize its major findings. From the ITEC experience, we conclude with some observations about the ambition of conducting an international study investigating the impact of computer use in school on children’s thinking and reasoning performance.

OVERVIEW OF THE ORGANIZATIONAL HISTORY OF ITEC

Project Background, Prior to May 1988

Because of the scientific expertise in Bulgaria with respect to the new area of computer use in education, a relationship with UNESCO was developed in which initiatives related to international exploration of this area could be stimulated. In this context, the First International Conference, “Children in the Information Age” was held in Bulgaria, in May 1985. This conference was organized by the (former) Lyudmila Zhivkova International Foundation, with assistance from UNESCO, the International Institute for Applied Systems Analysis, the (Bulgarian) State Committee for Science and Technical Progress, and the Education Ministry of Bulgaria. In response to recommendations unanimously adopted by the participants at this conference, preparations began for an international scientific project entitled, “Children in the Information Age,” to be cosponsored by UNESCO and other international organizations and institutes. One aspect of this project was to be the execution of “an international comparative study of the psychological consequences of computer introduction in the world of children of different cultures and traditions.”

The 23rd session of the UNESCO General Conference adopted a proposal to include this overall initiative which included the aforementioned research project, in its planned intergovernmental information program.

The second “Children in the Information Age” Conference was held, May 1987. Later in 1987, an initial planning meeting was held in Bulgaria to further discuss the international comparative study of the long-term effects on child development
of the use of computers. A first draft of a project proposal was prepared and circulated by UNESCO to a core group of international researchers, for comment and consideration. Several experts were then invited to a new meeting, in Bulgaria, in May 1988.

ITEC Project Initiation, 1988 to 1989

Under the support of the Lyudmila Zhivkova International Foundation, the Committee for Science of the Bulgarian Council of Ministers, and UNESCO, the "International Expert Meeting" was held in Tolboukhin, Bulgaria, May 1988. Thirty-two researchers from 14 countries participated in this meeting. During this meeting, the name ITEC was born, and major decisions about the design, theoretical framework, research questions, variables of interest, and the methodology of the project were discussed and agreed, at least in their first versions. Major aspects of these decisions—those that remained steady during the project and those that changed over time—are discussed later in this chapter. Assen Jablensky (then a professor at the Bulgarian Medical Academy) and Betsy Collis (then at the University of Victoria, Canada, and now at the University of Twente, the Netherlands) were invited to serve as coprincipal investigators of the project, and the preliminary organization of the project began.

The initial step was the preparation of the first project overview (May 1988) and a series of 11 "working papers" relating to key project issues. (This overview and the 11 working papers are available in the full Final Report of the ITEC Project; Collis, 1993.)

The second ITEC planning meeting was held in Sofia, Bulgaria, January 1989. During this meeting, the theoretical framework for the study was further delineated, and based on the analysis that had gone on during the previous 6 months, a revision of the research schedule planning and methodology of the project was worked out.

Following this, a first invitation to participate in the project was formally circulated, and the intentions of the project were presented at the UNESCO International Congress, "Education and Informatics: Strengthening International Cooperation," Paris, April 1989. The third ITEC project planning meeting was held, shortly after, in Sofia, Bulgaria, May 1989. The 15 researchers at this meeting made further refinements and decisions about project planning, variables and research questions, timeline and responsibilities, and expectations for national leaders. A major decision made at this meeting was to change the planned design of the project from a 3-year longitudinal comparative study to a two-phase approach, in which Phase 1 would be a pilot and exploratory study. This design change is discussed further in this chapter.

Formal letters of invitation were sent to potential national leaders and intensive communication concerning national participation took place during the period, June 1989 to October 1989. A new version of the Project Planning Document was prepared, a "Steering Committee" (six persons) and a project "Methodological Advisor" were appointed, and national teams and Chief Collaborating Investigators for each participating country were established. As of November 1989, project
teams consisting of researchers, schools, and teachers had been established in Bulgaria, Canada, China, Costa Rica, France, Hungary, Israel, Japan, Mexico, Netherlands, New Zealand, Portugal, Romania, Sweden, United States, Russia, and Zimbabwe. Twenty-four schools and 27 classroom teachers were selected for involvement. (Portugal later withdrew.)

The next ITEC planning meeting was held in Bulgaria, November 1989. Out of this meeting came the 40 pages of specific observation and interview instruments for Phase 1, the requirements for standardized videotaping of computer-use lessons, and other requirements for the national teams. Final timelines for Phase 1 data collection and analysis were established and materials were sent to all national teams.

**ITEC Phase 1: Organizational Procedures**

Preliminary descriptive materials were accumulated and a first summary report done for the 24 schools participating in Phase 1 during the period January through March 1990 (during this period, Portugal was still participating). This preliminary summary involved overall descriptions of the schools, interviews with the principal in each school, information on all the participating students (approximately 660), information about the teachers and interviews with the teachers, and summaries of 15-minute descriptive videotapes of each class and school.

Researchers began their observations of computer-use sessions in the participating classes during March and April 1990. Another project meeting was scheduled, in Bulgaria, May 1990. At this meeting, procedures for coding the videotapes were finalized. The three computer-use observations and videotaping and teacher interviews were completed by all the schools by August 1990. Extensive documentation, field notes, observational data, and summary comments were submitted to UNESCO in 1992 and distributed internationally in 1993 (Collis, 1993).

Because of several factors, including some radical political changes in the central and eastern European countries participating in ITEC during the period 1988 to 1992 and changes in the research responsibilities of many of the researchers, the infrastructure needed to support a continuation of the ITEC Project beyond its Phase 1 has not been materialized.

**CONCEPTUAL AND METHODOLOGICAL ISSUES IN ITEC**

**General Rationale for the Study**

During the project launch in May 1988 a number of fundamental conceptual decisions were made. Some of these decisions remained throughout its subsequent course, whereas others were modified. The objective of the project was to "involve the systematic examination of interactions among factors influencing the effects of IT on children's cognitive development using common variables, methodologies,
and instrumentation and through simultaneous focus on children in specific age groups in countries throughout the world" (Collis, 1993, p. 4). This core intention never changed. It was also agreed that the study should involve common definitions and operationalizations of its salient dependent and independent variables, should use common data-capturing instruments and procedures, and should "maintain an appropriate respect for the naturally occurring differences in embedding school, social, and cultural environments" (p. 5) that interact with any computer experiences that the child may have. Although this appropriate respect remained throughout the project, and operational consensus was reached on many of the key contextual variables that were studied, the quest for a concise and cross-culturally valid measure to represent higher level cognitive development did not reach a resolution (at least, not in terms of "concise" and "measurable"). It was also agreed that brief, episodic interventions involving technology were not likely to have a lasting and meaningful impact on children's higher level cognitive development, and thus adequate time had to be allowed for repeated child–computer interactions in natural classroom settings to occur. This recognition was maintained throughout the project, but was reflected not through a long-term intervention but by studying classrooms where child–computer interactions were already well established. The importance of culture as a contextual variable was to be reflected in a cross-national approach. This certainly was maintained throughout the project.

The initial project assumptions were summarized in May 1988 around six points:

1. The general interest of the study will be the relationships between the use of IT in education and children's cognitive and metacognitive development.
2. The study will be international and will involve a general framework of cross-cultural comparisons.
3. The study will involve the use of a variety of applications of IT within the school setting.
4. The study will consider the child in the context of his or her environment—as defined by variables relating to teacher characteristics, instructional strategies, school, family, cultural, and computer-use characteristics. It is accepted that change in aspects of any of these variable clusters can influence the overall system encompassing the variables, and therefore that a consideration of the child in isolation with a computer is not appropriate.
5. The study will be longitudinal.
6. The study will involve a core set of common research questions, variables, instruments, and other measurement techniques, applied to a same-age cohort at specific points in time identical in each culture (Collis, 1993, p. 5).

Of these initial premises of the study, all were, with some permutations, maintained. Also, the conceptual core of the study, the importance of social interaction for children's cognitive development as articulated in the theoretical work of the Russian psychologist Vygotsky (1966/1986, 1978), remained throughout, as did the awareness of interacting variables expressed in Item 4. However, how to express this
theoretical framework in terms of a manageable set of measurable variables was a topic of considerable debate during the 1988 to 1990 period. Many variables that the researchers agreed were influential with respect to children's higher level cognitive development, such as family circumstances and dynamics, came to be unwieldy in terms of standardized international assessment and compromises had to be made as to how to find a common system of categorization valid over diverse communities and cultures. The following passages, taken from a 1990 project document, indicate the theoretical framework finally agreed on as the basis of subsequent measurement and analysis in the study (Collis, 1993, pp. 118–121).

**Conceptual Core for the Study**

The conceptual starting point for the study was derived from the theoretical work of the Soviet psychologist, Vygotsky. Vygotsky emphasized the important role that social interaction plays in cognitive development (Gallimore & Goldenberg, 1989; Schoenfeld, 1989; Vygotsky, 1966/1986, 1978; Wertsch, 1985). Vygotsky (1978) hypothesized that an episode of cognitive development emerges through two cycles: "First, it appears on the social plane and then on the psychological plane. First it appears between people as an inter-psychological category, and then within the child as an intra-psychological category" (p. 163). "Learning in context" is seen as the motive force for cognitive development, and thus the analysis of children's thinking and learning cannot be separated from the analysis of the social organization in which the learning transactions occur (Levine, 1988; Schoenfeld, 1989; Zimmerman, Smith, Barthone, & Friend, 1989). Vygotskyan theory, therefore, gave the project its rationale for the expectation that computer use, embedded as it is in the social context of the school and cultural setting, can affect the child's higher level cognitive functioning (see also, Perret-Clermont & Schubauer-Leoni, 1989; Tikhomirov, 1988). Vygotskyan theory also underscores the necessity of studying the complex of variables pertaining to teacher and student interaction with regard to computer use in any consideration of the eventual effect of such use.

**Multidimensional Aspects of Computer Impact on Children's Cognitive Development**

Vygotsky's theories were not the only source of support for a multidimensional approach to the study of computers in education on children's metacognitive development. The extensive research that had already been conducted on aspects of the impact of computers in education substantiated the conclusion that such impact cannot be considered in isolation; it is inextricably embedded in and covaries with a large number of other variables (Clark, 1985; Collis, 1988; Eau & Hoyles, 1988; Hawkins & Sheingold, 1986). Technological innovations are "interpreted and shaped by the knowledge, experience, and setting of those teachers and students who encounter them" (Hawkins & Sheingold, 1986, p. 43) and "serve as mirrors of the minds and cultures" in which they live (Pea & Sheingold, 1986, p. 10).
Many clusters of variables have been studied, as critically mediating the impact of computer use on children's learning. Elaborations of clusters were compiled from a number of sources, including Cox, Rhodes, and Hall (1988), and Gayeski (1989), among many others (see Collis, 1993, p. 119, for an elaboration). From the research base and after discussions among the ITEC researchers, the following key contextual variables were focused on with ITEC:

- Family socioeconomic and educational levels
- Child's ability level
- Child's prior experiences and understanding with computers
- Child's gender
- Teacher's subject matter expertise and pedagogical skill
- Teacher's expertise with computer use in the classroom
- Teacher's attitudes and self-confidence about computer use
- Teacher's preferred instructional style
- Level of support available to the teacher with respect to computer use
- Availability and location of computers within the school
- School climate relative to technology
- Support of the principal
- Regional and national culture with respect to technology
- Type of computer use
- Frequency of computer use
- Software design characteristics
- Teacher–student interaction patterns
- Student–student interaction patterns
- Curriculum and student relevance of computer use
- Lesson integration of computer use

This sort of multifactorial system allowed us to investigate, not the impact of computer use on children's higher level cognitive development, but instead the combinations of factors that are most likely to be associated with productive metacognitive activity. This was a direction being endorsed by others as most productive for current research in the impact of computers in education (Phi Delta Kappa, 1987; see also Perkins & Salomon, 1989).

**Research Questions**

In the context of the theoretical framework presented here and after 2 years of iteration and discussion among the geographically dispersed research team, the following general research questions were finally accepted for the project:

- In the context of various combinations of background variables, under what combinations of characteristics of computer use, social interaction surround-
ing computer use, and instructional integration of computer use is a positive impact on children's higher level cognitive functioning more likely to occur?

• How do these sets of conditions vary in different cultures and countries?

Arriving at these research questions took compromise and much discussion. (The original set of research questions suggested for the project at its start-up in May 1988 were broader both in scope—"What factors facilitate or constrain the diffusion of IT usage in schools? How does the family both affect and be affected by the use of different types of IT in education?"—and in ambition "Are there measurable cognitive, metacognitive, and social effects on child development that are associated with the use of different applications of IT in education?"") Continual trade-offs were made between simplification and manageability, and scientific integrity and impact. For example, "Culture" proved very difficult to operationalize, and we finally decided to equate "culture" first with country, and then with "school-class-teacher grouping" in our analyses. Thus, we basically collected data by classroom units, and did not find a better way to conceptualize and operationalize "culture" as an influence. Also, we ended up doing virtually nothing with family variables, because of the complexity of dealing with such variables in a systematic way in a multicountry study. Again for reasons of complexity and sensitivity, we recorded nothing about the overall competency, intelligence, or imagination of the teachers involved, although we knew these variables make a critical difference in whatever happens in the school setting.

Thus, although it was agreed that a simple cause-and-effect approach ("What is the effect of computer use on children's higher level cognitive development?", with "computer use" being the independent variable and "higher level cognitive development" the dependent variable) was not possible, our recognition of the complexity of the issue also prevented us from finding an easy-to-articulate and straightforward focus for our project and analyses. Because we realized there would be no simple "answer" forthcoming from our investigations, we could see that our project was not going to generate a "result" that could quickly capture attention or have "statistically significant results."

This resulted in a scientific tension throughout the project. Should we use an "action research" or qualitative approach, where we focus on a better understanding of system and process, rather than an approach in which the causal impact of computer use was specifically under investigation? (For an elaboration of "formative experiments" as a sort of action research, see Newman, 1990.) But if we do this, what do we do with the "rich" mountain of observation data, field notes, and increasing complexity that emerges? How can we synthesize and make sense out of what we accumulate? Couldn't we have some sort of pretest/posttest, control group aspect? Couldn't we be getting "results"? Many of the national funding agencies involved with the project expected causal results in order to commit funds and support to the project, and also some of the researchers themselves would have preferred an hypothesis-testing approach, in which a control group, not using computers, was compared to an experimental group using computers, and pre–post
comparisons would be used to test an hypothesis of impact of computer use on higher level cognitive development.

This debate over an appropriate methodology for the study led to the major evolution in the project, from an expectation that the study could be carried out via a quasi-experimental design in which control groups in each country not using computers in school would be compared longitudinally with experimental groups using computers, to a so-called two-phase design, which is discussed later in this chapter. It also confronted us with the “dependent variable” problem, to be discussed in the subsequent section, as it was discussed continually throughout the project.

The “Dependent Variable” Problem

Clearly, we had difficulties selecting and operationalizing the context variables for our study, but these difficulties were not as substantial as those related to the “dependent variable” of the research—children’s higher level cognitive functioning. Everyone agreed such functioning was what we wanted to focus on (rather than a target such as, e.g., “improvement in mathematics skills”), because of the belief, or hope, throughout the world that computer use might have a particularly valuable influence on “higher level” thinking processes, such as problem solving, or critical thinking, or metacognitive strategies. This, however, relates to the major complexity of our study: What did we really mean by “higher level cognitive functioning”? Take the term metacognition as an example. In one typical example from the many reviews we collected, metacognition is defined as “the conscious attention to and control of one’s process and progress in a learning task” (Metacognition,” 1987, p. 13), but also as “thinking about and being aware of one’s thinking and involves self-monitoring, regulation, evaluation, and direction of cognitive activity” (p. 13). So the term metacognition refers to both the knowledge of one’s own thought processes and the regulation and control of these processes. However, in contrast, Perkins and Salomon (1989) defined cognitive skills as “general gripping devices for retrieving and wielding domain specific knowledge, as hands that need to configure to the kind of knowledge in question” (p. 23). How can we operationalize these concepts and measure them, validly and reliably, so that we could see how “metacognitive development” was affected by computer-use situations? Would whatever definition we use or any procedure we choose for measurement be meaningful and manageable in a cross-cultural study? The “dependent variable” problem was another reason for our two-phase design evolution.

The Two-Phase Design and the Research

Targets for Phase 1

The major change in planning for our study was taken in May 1989, when, after much discussion and exploration, we decided that our original intention of some sort of quasi-experimental comparison of computer-using and noncomputer-using classrooms relative to changes in children’s higher level cognitive functioning could
not, with scientific integrity, take place until at least a first phase of systematic exploration occurred. Thus, the idea of a two-phase design was accepted, with Phase 1 having the following preliminary research questions, seen as necessary antecedents for addressing the general research questions of the study:

- In the context of children using computers in the classroom, what are measurable or at least observable indicators of presumed "higher level cognitive functioning"?
- Do these indicators vary cross-culturally?
- If the cross-cultural variation in the indicators of "higher level cognitive functioning" is not too great, can a reliable methodology, usable in countries around the world, be found to measure the appearance and change of these indicators over time and in the complex context of the computer-use setting?

Based on the results of these preliminary investigations, it was hoped that at the end of Phase 1, we would be able to:

- Generate a hypothesis based on our general research question for comparative testing in Phase 2 of the study.
- Refine the methodology relative to the special needs of a multinational study.
- More sharply define the set of relevant contextual variables.
- Reach consensus about an operational definition of the outcome variable, "higher level cognitive functioning."

Other Methodological Decisions

Many other design issues confronting ITEC could also be discussed here, but because of limitations of time and space, only two are briefly mentioned (a full discussion appears in Collis, 1993). The two issues mentioned here relate to the selection of a sample for Phase 1, and to the use of videotaping as one of our data collection strategies.

Teachers. It was decided for Phase 1 to seek out existing classrooms in participating countries in which a teacher of 9- and 10-year-old children had a reputation of doing "good, interesting things" on a regular basis in terms of computer use with children in his or her instructional setting. We made this choice in order to maximize the chance of finding measurable, observable indicators of higher level cognitive functioning by making the teacher variable as controlled (and strong) as possible. This decision was also made in order to somewhat control the variables relating to teacher experience with computers, teacher attitude about computer use and about innovation in instruction, availability of computers and usable software, school and community support for computer use, and experience of the students involved with computer use in an instructional setting. The decision was also made for a practical reason—the project had no funding to set up computer use situations
in ‘ordinary classrooms,’ and no funding or time to train teachers in some sort of internationally consistent manner. Thus, we moved from an interventionist to a naturalistic approach, and consequently lost even more any margin of hope we might have had of ‘showing’ the effect of computer use on children’s cognitive functioning, at least during Phase 1. We also recognized the limitations of generalization with such a sample selection procedure, as we had predominantly good, imaginative, exceptional teachers and exceptional school situations in our sample. However, from this sample we could use a ‘backward mapping approach’ (Fullan, Miles, & Anderson, 1988) to address the preliminary research questions for Phase 1.

**Videotaping.** Another methodological decision we made was to supplement our various observation and interview procedures with a standardized protocol for videotaping school and computer-use situations (see, e.g., Schoenfeld, 1989, for a discussion of the value of videotape analysis when a team of researchers are working on a broadscale research study). From this decision, we accumulated approximately 100 video fragments, each of about 15 minutes—in general, 4 per participating class. These include in-depth observations of at least three separate classroom lessons involving computer use of the type that the teacher felt would be likely to stimulate what he or she believed to be valuable higher level cognitive functioning on the part of the students. (Each researcher was left to work out with the teacher what these computer activities might be.) For each observation, structured videotaping was done of the overall classroom environment in which the computer use occurred; other aspects of the lesson before, during, and after the computer use; and teacher–student and student–student interactions before, during, and after the computer use. Following each in-depth observation, a detailed interview was conducted with the classroom teacher, in which he or she discussed the behaviors or other indicators of higher level cognitive functioning in the children that the teacher felt occurred during the lesson. Following this interview, a written analysis was done by the researcher as to the extent to which he or she agreed with the teacher’s appraisal of possible higher level cognitive functioning among the students. We then developed and validated coding procedures for the videotapes based on the “mapping-sentence technique” (see Peled, 1993), and attempted to use them to triangulate the teacher and researcher reports of indicators of “higher level cognitive functioning.” Using the videotapes added to the richness and complexity of the data collected for the study, but also added considerable time and analysis loads on the researchers.

**Other Instrumentation**

A 40-page battery of observation instruments and interview forms was sent to each national leader at the beginning of 1990. This battery consisted of 12 forms, each with its own procedures for data collection. The forms were first circulated among the participating researchers, for pilot validation and comment. The forms were as follows:
Form A: General sample description, relating to demographic information about each participating school, teacher, and class, including prior experiences with computers.

Form B: General description of the school and its culture, including an overall description of the school, and more detailed information about the school's experiences with computers.

Form C: Interview protocol for the school principal.

Form D: Student information, including the teacher's responses to various questions about each child, and responses from each student relating to his or her feelings about solving problems and learning new skills.

Form E: Interview protocol with the teacher, including information about the teacher's teaching experience and methods, and his or her use of computers with the children involved in the ITEC study.

Form F1: Transcript and summary of the descriptive videotape, relating to the 15-minute videotape of the school, its neighborhood, and the teacher and class in noncomputer activities.

Form F2: Summaries of the computer-use lessons, including summary information about the students' engagement with computers during the lessons.

Form G: Researcher's summaries of the computer-use settings, during the videotaped computer-use lessons, including specifics of hardware and software, an instructional overview of each lesson, and observations concerning the quantity and quality of student–student and student–teacher interaction during each lesson.

Form H: Transcript and summary sheets for the three computer-use lessons.

Form I: Interview protocol with the teacher, relating to the teacher's impression of higher level thinking displayed by the students while engaged in computer use.

Form J: Researcher's summary of the computer-use activity, including any comments pertinent to the study.

Form K: Coding forms for the videotapes.

In addition, each researcher was asked to prepare an in-depth report on his or her experiences with the project, including a summary of the motivations of those involved for participating in the project, the researcher's own impressions of behaviors assumed to demonstrate higher level cognitive activity related to computer use, and the researcher's own suggestion for a response to ITEC's general and preliminary research questions.

All these forms, as well as information about their development and validation, are described in full in the final report (Collis, 1993). All classroom-observation data was collected during the period January through June 1990, and completed sets of forms were returned by the researchers by the end of 1990.
Has all this careful effort accomplished our Phase 1 goal of better conceptualization and measurement of our “elusive” dependent variable? We comment on this following a summary of the results of the data collection in the next section.

RESULTS

In this section, we present a sampling of results from the various observation and interview forms. We then combine these results to address the preliminary questions for Phase 1 and also the ITEC general research questions.

General Sample Description

Twenty-two schools from 16 countries completed a full participation in the study. Of the 16 countries, Mexico had 4 schools; Romania, France, and Costa Rica had 2 schools each, and the remaining countries—Bulgaria, Canada, China, Hungary, Israel, Japan, the Netherlands, New Zealand, Russia, Sweden, the United States, and Zimbabwe—had 1 school each. There was one participating class from each school, and one participating teacher per class, with the exception of Hungary and Japan, where there were two teachers involved with each of the participating classes. However, only one teacher per class was included in the analysis. There were approximately 630 children involved (over the year of data collection, there was some fluctuation in total student numbers); the mean number of students per class was 30; the children were almost all in the age range 9 to 10 years; they and their classes were not judged as exceptional relative to other children and schools in their regions with regard to noncomputer-related characteristics. In 17 of the 22 classes, more than half of the children had previously experienced computer use in schools. Of the teachers, 9 were males and 14 were females, with an average of 15.7 years of teaching experience. Nineteen of the teachers had some training with regard to educational computer use, generally with some exposure to word processing, educational computer games, and other types of software, to the use of drawing software, and to fundamentals of BASIC and LOGO programming. However, the nature and extent of the teachers’ training experiences varied widely and often was only very limited.

From the overall analysis of the demographic data, it could be said that, other than being in a school where computers had been provided for young children and a class where the teacher was already making use of computers, the children, teachers, and schools in the ITEC project were not exceptional in any particular characteristic.

A Closer Look at the ITEC Schools

- In the ITEC final report, 24 pages are required to summarize the contextual variables pertinent to the ITEC schools (Collis, 1993, pp. 138–162). Highlights of this summary include:
• The schools were almost all public schools, located in major cities, and often could be described as middle-class in terms of parents' educational levels.
• Although in 12 of the 22 schools fewer than 10% of the children had computers at home, and in 16 of the schools fewer than 10% of the teaching staff had computers at home, the schools themselves had more computers than normal for schools in their countries, with 17 schools being in the top 25% of schools nationally and 4 schools being near the average.
• The computers themselves (296 among the 22 schools) were in many different locations within the schools, and of varying types and ages.
• The schools made a variety of uses of their computers, with all of them indicating that the computers were used as objects of study in themselves, as well as tools and, with more diversity, for use with specific educational software.
• Despite having relatively superior computer resources compared to other schools in their countries, fewer than 10% of the teachers in the schools were making use of the school computer resources.

Thus, the ITEC schools were different in that, for a large variety of reasons, they had managed to acquire an exceptional amount of computer resources (relative to other elementary schools at that time). The ITEC teachers were unusual in that they were making use of the computer resources. Apart from this, there was no particular pattern in where the computers were located or how they were used or in the characteristics of the software that were used.

**Principals' Opinions About Computer Use**

The school leader is a central figure in deciding what and how computers are being used in the school. The amount of computer resources the ITEC schools had showed that the school principals were supportive in computer use. The interviews with each of the school principals were carefully translated and coded, by two different teams of ITEC researchers, and the results compared and verified (see Collis, 1993, pp. 163–180). As a summary of these interviews:

• The principals believed that computers in their schools were bringing positive benefits to the schools, although they gave many different illustrations of what these positive benefits were. Most frequently stated was the belief that computers raise the enthusiasm of the students.
• The majority of the principals felt there was not enough good software available. They indicated little concern about the costs associated with computer use or organizational issues relating to computer use and maintenance.
• The principals agreed that teacher training was a major concern.
• The principals felt that computers could be of benefit to all students, at all ages, and saw no particular target group for whom the computers would be most, or least, appropriate.
• The principals were already satisfied with the quality of student–student and student–teacher interactions in their schools and saw no reason to fear that computer use would diminish this quality. They were not looking to technology to compensate for poor conditions in their schools, but to take advantage of opportunities for strategic development.

Thus, the fact that the principals of the ITEC schools were unanimously positive about their schools, and about the benefits of computers in those schools was probably a key factor in making the schools exceptional in terms of computer experiences available to at least some classes of children. What those benefits were varied and tended to be expressed in global terms, but were seen as good for all students.

**Summary of the ITEC Students**

Although the ITEC students were described by their teachers as predominately average in their families’ socioeconomic levels, and predominately average in their academic achievement levels, the majority of them were described as very interested in computers. A wide range of computer-use activities were being engaged in by the children, including word processing, the use of drill and practice programs and other sorts of educational software, BASIC and LOGO programming activities, educational games, and the use of drawing and graphing programs. The teachers saw no tendency to favor individual or group work on the part of the children.

The students described themselves as not likely to give up easily when a task is hard, as preferring to find their own ways to solve problems rather than being given instructions, as sometimes getting irritated if someone revealed how to solve a problem while they were still trying to work it out, and as offering to help their friends with problems. In general, the attitudes of the students toward problem-solving situations could be described as positive. Although causality with respect to computer use cannot be claimed for these positive problem-solving attitudes, the fact that these were computer-using children and that they apparently felt good about themselves as problem solvers was a pleasing correlation, and one that spanned the many different cultures and countries and ways of using computers represented in the study.

**Summary of Teachers’ Interviews**

Other than being enthusiastic users of computers with their classes, there were no particular similarities among the teachers in terms of their ages, years of experience, training, and ways of using computers for instructional purposes. There were many differences in teaching style, in who the teacher turned to for support and help, in the sort of training and computer-use experiences the teachers have had. However, there were also a number of similarities among the teachers:
• Most took their students to a computer laboratory for their computer use.
• Most supervised their students themselves when the students were using computers.
• Like their principals, most felt that there was benefit for all types of students with computers.
• All believed there were many benefits that could come to their students through computer use, but like their principals, they varied widely on the types of benefits cited (in this case, 26 different categories of benefits were identified, with the one being mentioned most often, "it would help independent work," which was named by 7 of the 23 teachers).

The teachers were divided as to whether they had changed the way lessons were taught or organized because of the computer. Of the 13 who answered yes, many felt that their lessons had become more student-centered, with more time for individualized instruction. However, a number of the teachers felt that the computer affected the classroom atmosphere rather than their individual styles of teaching, with the computer being simply another tool integrated into their existing instructional program. Regardless of whether the teacher had changed his or her teaching style, most felt their students were more self-reliant than "before," that they looked less to the teacher for help, participated in more student-centered discussions, and were more enthusiastic about computer-use lessons than other lessons. Every teacher was of the impression that positive changes were occurring with his or her students because of, or at least alongside of, the students' use of computers.

Summaries of Context and Computer-Use Sessions

The remainder of the forms related to the capturing of information and impressions about the dynamics of the class and teacher as a whole, with and without computer use. As indicated earlier, considerable time and effort went into the coding and interrelating of the school and classroom observations. The final report summarizes these analyses (Collis, 1993, pp. 210–256). As one approach, analyses were done by grouping the classes into "industrialized nations," "East European," and "Third World" categories (with China, Zimbabwe, Mexico, and Costa Rica placed in the latter category). There were predictable differences among these groups in categories such as the types of computers that were available to the classes, but no significant differences were identified on variables relating to student involvement with computers, in student difficulties with computers, or on instructional relevance of computer use. In many respects, the children were similar regardless of part of the world category in which they were placed, such as with their near unanimous interest in computer use or the observation that computer use occurred most often in the context of mathematics or informatics lessons, with geometric topics the most frequent.

However, a wide variety of software programs were being used in the ITEC classrooms. Of all the computer programs used, the programming language LOGO
was perhaps the most popular one, accounting for 40% of the total use. The other language used was BASIC (10%). These programming software were mainly used as a tool in mathematics instruction, in some open-ended projects, and to control some external devices. The use of LOGO to enhance the learning of mathematical concepts was quite common in mathematics lessons. For example, in three classroom observations, LOGO was used to teach geometrical concepts (e.g., axial and central symmetry). In other lessons, more open-ended use of LOGO was adopted. For example, in an Informatics class, LOGO was used mainly to help develop children's problem-solving skills and cognitive abilities. The class emphasized a wide variety of applications that fostered interaction and creative practices.

Other than programming, about one quarter of all the videotaped computer lessons used computer-assisted instructional programs (CAI), in the forms of drill and practice and tutorial. They were used in a variety of subject areas such as informatics, language, and again, mathematics (e.g., a drill and practice on subtraction of fractions). More open-ended software programs such as database and graphics programs as well as problem-solving programs were used, accounting for the remaining 25% of the use. In database activities, for example, students were asked to construct a database using information they had collected on a field trip to various beaches. They used key words to categorize information and at a later stage came up with questions to query the database. In one of the problem-solving activities, students were divided into groups of two to three and used a problem-solving program called "Transylvania." In this program, a woman was trapped inside a statue and the objective of the user was to rescue her. To achieve this goal the students had to work out the goal and the strategy and acquire the tools required along the way. Hypercard, graphics, games, and simulation software were also used in several classes.

The Dependent Variable:
Higher Level Cognitive Processing

Clusters of Observable Behaviors. Although context is critical, the core of the ITGC investigations related to children's higher level cognitive development. The preliminary research questions of Phase 1 focused on finding measurable or at least observable indicators of metacognitive activity. The researchers synthesized the comments of the teachers (from Form I), of themselves (from Form I) and their other notes, and from the syntheses of the videotapes in order to look for indicators. From the teachers' own words (translated into English), hundreds of comments were extracted (see Collis, 1993, pp. 245–247), and grouped into 11 clusters:

1. Reflection and evaluation of one's own work and of the work of others.
2. Consideration of alternatives.
3. Creativity.
4. Transfer and extrapolation.
5. Seeing new forms of representation.
6. Debugging.
7. Developing strategies for working with others.
8. Showing better performance through better results, better questions, and better work habits.
9. Generating and comparing examples.
11. Problem solving.

The list of behaviors described by the teachers as being present when their students used computers is impressive, especially when we remember that these teachers were describing in their own words the behaviors they felt they observed in their 9- to 10-year-old students. The list shows a certain amount of convergence, with no pattern of differences in focuses among the different countries and parts of the world. The list also shows again that the domain of interest in ITEC was complex. Something very good was happening in these classrooms when the students used computers, but that something was multifaceted. The teachers perceived it, and were enthusiastic about it, in its various manifestations.

Validation of Clusters. In order to check the researchers' opinions with those of the teachers, completed sets of observation forms and comments sheets (Forms I, J, and K) from 44 videotaped lessons involving 12 of the participating countries and 16 of the classes were analyzed in detail. The researchers identified 10 clusters of indicators of higher level cognitive functioning, and indicated, from the 44 lessons for which complete data were available, the extent to which they perceived the clusters to be observable. Table 4.1 (taken from Lai, 1993) summarizes these conclusions.

Column 5 of Table 4.1 shows that the majority of the researchers observed at least some children displaying indicators of higher level thinking behaviors in the computer-ue lessons. In fact, only three indicators of higher level cognitive functioning (comparing similarities and differences, generating new ideas, and recognizing relationships) occurred in less than 60% of the observed lessons. However, the behaviors that were "generally displayed" (Column 4) more than being displayed "just by some students" (Column 3) are much more dispersed, with the highest frequency (42%) being for "Evaluating One's Actions."

Examples of Behaviors Demonstrating Higher Level Cognitive Functioning Skills. A wide variety of examples of higher level cognitive functioning skills were observed by the teachers and researchers in different educational and cultural contexts in this study. To illustrate this, we take problem solving as an example. Most of the videotaped lessons involved some sort of problem-solving activities and various problem-solving skills were displayed. In problem solving, one way to better understand a problem is to relate it to a previous problem, or to one's previous experience. It has been observed in several ITEC classrooms that learners in a computer-based environment were able to relate their own concepts to the programs they were using. For example, in one computer session, when students were
### TABLE 4.1

Percentage of Observed Courses-Using Lessons in Which Researchers Saw Various Indicators of Higher Order Cognitive Functioning (Total Number of Lessons = 44)

<table>
<thead>
<tr>
<th>Behavior</th>
<th>(1) Observed Lessons in Which the Behavior was Generally not Displayed (%)</th>
<th>(2) Can't Say (%)</th>
<th>(3) Behavior Displayed But Only by Some Students (%)</th>
<th>(4) Behavior was Generally Displayed During the Lesson (%)</th>
<th>(5) Total Observed Lessons (3+4) in Which Behavior was Displayed (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Relating a problem to previous problems</td>
<td>16</td>
<td>12</td>
<td>32</td>
<td>40</td>
<td>72</td>
</tr>
<tr>
<td>2. Formulating appropriate questions</td>
<td>24</td>
<td>0</td>
<td>64</td>
<td>12</td>
<td>76</td>
</tr>
<tr>
<td>3. Trying alternative approaches</td>
<td>24</td>
<td>8</td>
<td>36</td>
<td>32</td>
<td>68</td>
</tr>
<tr>
<td>4. Evaluating one's actions</td>
<td>21</td>
<td>0</td>
<td>37</td>
<td>42</td>
<td>79</td>
</tr>
<tr>
<td>5. Analyzing problems</td>
<td>12</td>
<td>8</td>
<td>44</td>
<td>36</td>
<td>80</td>
</tr>
<tr>
<td>6. Recognizing relationships</td>
<td>13</td>
<td>33</td>
<td>29</td>
<td>25</td>
<td>54</td>
</tr>
<tr>
<td>7. Generating new ideas</td>
<td>32</td>
<td>28</td>
<td>28</td>
<td>12</td>
<td>40</td>
</tr>
<tr>
<td>8. Synthesizing information</td>
<td>17</td>
<td>21</td>
<td>33</td>
<td>29</td>
<td>62</td>
</tr>
<tr>
<td>9. Observing central issues and problems</td>
<td>20</td>
<td>8</td>
<td>40</td>
<td>32</td>
<td>72</td>
</tr>
<tr>
<td>10. Comparing similarities and differences</td>
<td>16</td>
<td>56</td>
<td>12</td>
<td>16</td>
<td>28</td>
</tr>
</tbody>
</table>

engaged in the setting up of a database, they used their personal experiences (i.e., their visit to the beach to see what the tide washed up) to establish key words for database development. In another class it was also observed that some students used their previous experience to help analyze their tasks and figure out what was expected of them.

One efficient way of tackling a problem is to represent it in another way. In several programming situations in this study students were seen using aids to represent their problems. For example, students used notes and diagrams to represent their problems and to do their initial planning before programming in LOGO.
Several researchers have observed that some students had expressed the notion of goal achievement. For example, some students had clearly established their goals of finding or transferring LOGO primitives in their computing activities. In one videotaped lesson, it was observed that students achieved their goal by coordinating the solutions of various subproblems. Initially some students in this class tried to construct one long program. To them, dividing the task into subtasks (problem decomposition) was extra work. But they failed to debug their program and finally came to realize that they should deal with one part of the program at a time (e.g., constructing a picture of a fantastic creature's head instead of the whole creature).

It was clearly seen that the computer lessons provided students with the means to try out alternative approaches to the problems they are supposed to solve. For example, it was observed by a teacher in a database activity that his students did formulate questions and test these questions at the computer. In the follow-up discussion students suggested alternative solutions to problems they had encountered, which often involved reflection on different procedures proposed. Similar observations were reported by other researchers.

The computer-based learning environment sometimes "forces" students in a problem-solving mode and in the process will enhance the learning of problem-solving skills. For example, in one computer session the students were asked to select six words to describe themselves to an alien visitor. In this exercise the students need to analyze what kinds of things described a person and what characteristics made him or her unique as an individual or a culture. They also need to use analysis skills to figure out what was expected of them and reconcile it with their previous experience. They were also using a new computer skill in this activity—combining the paint and draw modes of SuperPaint to create a picture. This activity was an example of how different higher level thinking skills were exercised in a computer-based learning environment.

"Something Good" is Indeed Happening. Thus, with all these indicators of higher level thinking no singular dependent variable emerged, although the richness and quality of the clusters of behaviors that were validated by the researchers through a variety of synthesis methods are impressive. "Something good" was indeed happening in these computer-use lessons. There did not seem to be a cross-cultural difference in this "something good," in its various manifestations in many different types of lesson and computer-use situations, but it was not reducible to discrete measurable variables that could be used as a basis for hypothesis testing.

Summary of the Results

Summarizing the results of Phase 1 of the ITEC Project requires nearly 200 pages of comment in the final report (Collis, 1993, pp. 133–320) and sometimes the researchers themselves saw different interpretations of the myriad data and observations and interactions that occurred over the 4 years of the project and the year-long period of school and classroom observations. However, agreement was clear about the conclusions that follow.
Something Good, in Terms of Children's Higher Level Cognitive Development, was Happening in the Computer-Use Classes. A dominant impression from all the data sources was that the computer-use lessons, in their great diversity of forms and attributes, were happy and productive learning situations. Computer-use activities that the teacher and researcher felt had positive cognitive benefits for the children involved were not dependent on particular hardware or software characteristics or classroom environments. Enthusiastic engagement in learning, and presumed higher level cognitive functioning, were taking place where there was only one small classroom computer as well as where there was a lab of networked Macintoshes. Apparently beneficial classroom computer use did not depend on doing a certain type of computer-use activity nor did it need some necessary baseline amount of computer access or some specific type of computer or type of software. In contrast, the way the teacher introduced and organized the computer use was important, the way he or she interacted with the children while the computer use occurred, and the way he or she attempted to reinforce and bring closure and transfer to the computer-use experiences after they were concluded were clearly important. Students interacting with each other, displaying enthusiasm in the way they interact with the learning material, and showing a willingness to sustain this quality of absorption with the learning task over considerable periods of time, also seemed to be common characteristics of the computer use in the classrooms in the ITEC Project. This is ITEC's good news.

Measuring the "Something Good" is Still Difficult. We found encouraging convergence toward visible indicators of presumed higher level cognitive functioning, as teachers and researchers in many different parts of the world came up with the same type of indicators in very different cultural and physical settings. Measurement of higher level cognitive functioning in the realistic social setting of the dynamic classroom, however, remains very difficult to do. Teachers were convinced "good things are going on," the videotapes show the positive characteristics described, but finding a cross-culturally manageable way to validly and reliably measure and document these "good things" did not emerge. Perhaps it is unfair to call this "bad news," but instead challenging news: our convictions about the powerful stimulating effect of classroom computers remain elusive to codify, quantify, and document.

There Seems to Be Only One Contextual Variable Consistently Associated With the Higher Level Cognitive Behaviors: A Good Teacher. Our data from 16 countries and 22 classrooms make it clear that there is no particular rule to follow with respect to computer use for young children. We have seen many different types of lessons, computers, software, school settings, types of student–computer-use patterns—it didn't seem to matter relative to the cognitive indicators that were displayed. But one variable was constant in all our videotapes and observations: a good teacher. What "good" means is another difficult to define concept, and is not characterized by a particular set of behaviors. The ITEC teachers used different teaching strategies, certainly had different personalities and styles of
interaction with their students, and used the computers in many different ways. But we, as experienced educators ourselves, recognized quality in these teachers. The ITEC teachers were selected as atypical to begin with, as already using computers with young children in a way that had gained the attention of their peers. We have no way of saying if the computers caused these teachers to be good teachers, but we doubt it. Nor do we have data relating to "ordinary" teachers, those that were not already through their own initiative working with computers.

SUMMARY AND REFLECTIONS

Did We Answer Our Research Questions?

The major research question in ITEC was: "In the context of various combinations of background variables, under what combinations of characteristics of computer use, social interaction surrounding computer use, and instructional integration of computer use is a positive impact on children's higher level cognitive functioning more likely to occur?" How do these sets of conditions vary in different cultures and countries?

Our conclusion to these questions was that given a good teacher, and a teacher willing to be an innovator with computer use, a positive impact on children's higher level cognitive functioning seems to occur. Such a teacher will ensure that the computer use is integrated in an attractive and well-planned learning experience and will interact in close and responsive ways with his or her students as they work with the computers. But these are characteristics of good teaching, not revolutionary insights related to computer use. Thus, optimal combinations of types of computer use, computer software, and ways of using computers did not emerge. The good news about computers may well be that for a good teacher who wishes to innovate with computers and who has the support of the school principal, the computer can be a tool for the development of higher level thinking regardless of the amount of hardware and software available, regardless of the training available to the teacher, regardless of the type of lesson and number of students in the class. This was the ITEC experience.

As for culture-related differences, of course we saw them, but they were most visible in the classroom settings preceding or following computer use. Once the children were at the computers, they almost always were interacting with each other in a task-directed way about the content of the computer-involved activity. Without exception, they appeared engaged in their tasks, enthusiastic about the computer use, not focused on the computer itself but rather, what they were using the computer to do. We saw this sort of quality of absorption in the learning task sustained over considerable periods of time, in all of our classrooms. Thus, these were common characteristics of the ITEC students, again regardless of type of hardware and software, type of computer use, and lesson characteristics, and cultural context. It appeared as if the computer brought a culture of its own that transcended the differences in the natural cultures of the classrooms.
4. A CLASSROOM PERSPECTIVE

As to the preliminary research questions for ITEC and the expectations of ITEC for its Phase 1 results we found convergence over culture and setting for general types of indicators of higher level cognitive functioning, but not convergence enough to delineate measurable variables that could capture the wealth of different types of quality thinking and metacognitive behavior that was going on. The clusters of behaviors appeared, regardless of country or culture, which is good news for subsequent research.

If we had to suggest a hypothesis for a Phase 2 of ITEC based on the Phase 1 explorations, perhaps it would be to compare the presence of the higher level indicators in classrooms not using computers with those that are, but we already know that any significant differences that would occur could not be accredited to the computer itself, but would be inescapably interrelated with the school, school principal, and the teacher. But this is what we and many others already knew: The effect of computer use on children's higher level cognitive functioning cannot be considered outside of the social and cultural environments affecting the child—his or her community, school, teachers, and school leaders.

What Are the Contributions of ITEC?

However, we do believe that ITEC made major contributions. Extensive pilot testing in the national sites; regular international working meetings in which scientists from the participating countries integrated their ideas and experiences with respect to the impact of computer use in schools into the design and development of the project yielded an observation methodology that has proved to be manageable in an international setting and whose validity has so far been supported. Thus, our expectations as to the development of a protocol usable for classroom observations in a multinational research project have been reasonably satisfied.

More generally, we feel ITEC has made some other general contributions:

- For the field in general, we have documented examples of good practice with computer use in widely varying conditions around the world, that can give encouragement to teachers with vision and enthusiasm regardless of their local conditions.
- We have made the case that there is no "best" or "right" way to use computers with young children, but a myriad of ways, so that fit to local situation can be found.
- We have shown that, within a wide range of types of teacher training, of hardware and software, and of lesson approaches, that children appeared enthusiastic and absorbed in their learning activities, and that good results occurred that transcended the actual content of those activities.
- We saw absolutely no evidence that the 660 ITEC children, regular computer users, were developing any negative social or intellectual characteristics along with their computer use. The children themselves, and their teachers, felt the children were developing more self-reliance, more persistence, and better cooperative skills in problem situations.
And also, although not a contribution of the study for the world in general, the ITEC Project has been valuable for its researchers themselves. We have learned much about each other and each other's countries and approaches to research activity. We have developed a strong network of relationships among ourselves that can still be tapped years after the project has finished. We have watched ourselves function as epistemologists: thinking about our own thinking as we compromised and interpreted and summarized. We have seen among ourselves the phenomena of the computer as a stimulus to reflection and creative thinking, the same sorts of phenomena as we were looking for among the children in the study. As with our ITEC children, we cannot precisely measure the impact of this metacognitive activity in ourselves but we are confident that we have grown from it.

REFERENCES


4. A CLASSROOM PERSPECTIVE


