Quo Vademus?

The Transformation of Schooling in a Networked World

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> "Every student needs a grandparent to link them to the past and a PC to take them into the future." (UK01-Greenfield)

1. In early 1998, at an informal meeting of the OECD Ministers of Education, the Centre for Educational Research and Innovation (CERI) was directed to develop plans for a programme on ICT and the quality of schooling. The resulting programme that was approved and subsequently funded by the majority of OECD countries had three areas, Markets and Partnerships, Quality Assurance, and Impact Studies. Areas 1 and 2 have completed their work, which can be found in three OECD publications that are available via the OECD Web site, <www.oecd.org>. Area 3 embarked on two major impact studies: cases studies of ICT and organisational change, which are reported here, and quasi-experimental studies of the factors that affect the learning of ICT and information handling skills, which will be reported in a forthcoming document. An OECD publication containing the combined reports of the two studies is due to appear in June 2002. The current report summarises the findings from 94 case studies done by the 23 countries participating in the study[1].

2. We are deeply appreciative of the work done by the research teams from the participating countries, first in working with us to refine and focus the methodology for this study and then in executing their separate studies and documenting them so richly. No summary can do full justice to the many descriptions, issues, and conjectures presented in these reports and we make no claims for offering any more here than a plate or two from the findings in the sumptuous banquet of case study reports that we received. We hope that the reader will be tempted sufficiently by these samples to feast on the reports themselves, which are publicly available on the OECD Web site identified in the paragraph above.

[1] The participating countries are listed in Appendix B. Twenty-one of these were OECD members; the other two were Israel, which has observer status with OECD, and Singapore, which has participated in other OECD activities.

BACKGROUND

> "The binary digital system-Brother One and Sister Zero-that makes computers possible is a kind of light/dark relationship to begin with, and when you start to factor in the electron rather than the word as the primary information link between the brain and the external world…" Tom Robbins, Fierce Invalids Home From Hot Climates. New York: Bantam Books, 2000, p.180.

3. Two of the priority issues expressed by the OECD Ministers in the 1998 meeting mentioned above concerned the impact of ICT on schooling in general and on skills acquired by students in particular. Case studies were designed to address the former issue while quasi-experimental studies were designed for the latter. The background and methodology for the case studies is defined in two working papers that were circulated to member countries: Methodology for Case Studies of Organisational Change. (Version 12 -21 June 2000) and A Workbook for Case Studies Of Organisational Change (Version 9b—8 August 2000).

4. The primary goal of the case studies is to understand how ICT relates to educational innovation. Within the OECD countries two far-reaching changes are occurring in K-12 schooling. First, a variety of instructional reforms are under way, driven by a perceived need to reorient schooling from rote learning, shallow but wide coverage, and individualistic learning processes to higher level skills, problem solving, in depth study, and collaborative learning. These reforms take different forms in different countries. Some are using curriculum standards and performance assessments to drive teachers and administrators to account for the success of all learners, including especially those traditionally marginalised. Other countries are depending more on improved staff development and revised curricula, emphasising learning to learn ability as well as interactive, collaborative skills. Life-long learning is also a major concern of the OECD countries, although policies and programs to stimulate and improve this area are not often visible at the K-12 levels.

5. In parallel with educational reform, and sometimes indistinguishable from it, is the educational ICT revolution. Every OECD country is working to install networks in schools, connect them to the Internet, and ensure a workable configuration of multimedia computers, educational software, technical support, and ICT-savvy teachers. Building initially on the foundation of educational computing created in the 1980s, which centred on computer-assisted instruction, this movement took a dramatic turn away from this tradition in the 1990s by stressing professional development in ICT for teachers and focusing on integration of ICT into a modern, teacher-taught curriculum. Computers moved to the classrooms as well as to the hallways, libraries, and laboratories and became productivity tools for students and teachers as well as communication hubs. This approach contrasted dramatically with the test-and-drill, learning games, and teacher-proof individual instructional programs and integrated learning systems that dominated ICT use in many countries in the past decades.

6. The case studies reported here probe the link between successful implementation of educational innovation and successful installation and use of ICT: does one tend to drive the other? Can one be used as a leverage for the other? Of particular interest is the school as a social organisation: its operational

dynamics and the conditions and processes through which it changes. These studies have identified sites where major innovations have occurred and been accompanied by major investments in ICT, and studied specific issues related to ICT and innovation as outlined below.

7. We use throughout the remainder of this report the term *innovation* as a general designation for substantive, positive change in a school system, regardless of whether the change involved instituting a novel procedure or a traditional one. In some countries *reform* is a synonym for *innovation* but in others it implies a deliberate policy from a central body that may or may not precipitate change or innovation within any specific school. *Change* conveys some of the sense of *innovation*, as the latter is used here, but *change* could be negative or positive and of any magnitude. *Change* can also occur without alteration of beliefs and values and although we cannot verify that all of the innovations reported here penetrated deeply into their school cultures, the concern in this report with innovation is, in the ideal, a concern with such deep change. For this study, the innovations of interest are those that occur at a school level, regardless of whether they relate to students, teachers, school organisation, or administration. For the most part, this restriction ruled out cases where the only innovation was a program or project initiated within a single classroom or small group of classrooms. It did allow school wide curriculum change as well as administrative improvements and enhanced connections between schools, parents, and local communities[2].

[2] The IEA study, SITES-2, is examining innovative classroom practices through case study methods. The OECD/CERI case study was planned in co-operation with SITES-2 and a combined protocol was developed for those countries doing both studies.

METHODOLOGY

> "And so I was decided to consecrate myself to this study of the essence of things, to establish its true nature, but how should I do this, by what means?"
>
> Marcel Proust, A la Recherche du Temps Perdu: Le Temps Retrouvé [Remembrance of Things Past: The Past Recaptured] Vol. II. Trans. from the French by Frederick A. Blossom. New York: Random House, 1932, p. 999.

Case study approach

8. The methodology used was explanatory case studies as defined by Yin (1993, 1994). Such a methodology is preferred for evaluation when the program to be studied is not easily distinguished from its context and there are more variables of interest than projected data points. Stated differently, an explanatory case study is an appropriate design for an evaluation when the context of a project or program is assumed to contain important explanatory variables, the boundary between program and context is not easily distinguished, and the number of variables of interest potentially exceeds the number of data points obtainable. An explanatory case study differs in important ways from an ethnographic study. The former requires that (a) data collection is theory driven, with specific issues or questions, stated as hypotheses, defined ahead of time, (b) rival hypotheses are also defined ahead of time, and (c) data collection is focused on what is relevant for resolving the key hypotheses stated in (a) and (b) (cf. Chen, 1990; Fetterman, 1989; Stake, 1995). It is generally true, also, that case studies are more time-limited than ethnographic studies, but this may not always be so.

9. With the exception of a Teacher ICT Practices Survey that was intended for all teachers at a site, almost all of the data collected for these studies is qualitative. (A few reports do contain test scores from student assessments, however.) We do not claim, therefore, to be able to deliver experimental results or to develop theories on the basis of the results obtained. We do draw conclusions, however, so we do need to attend to what these outcomes represent and on what basis they were created. As a general background to the methodology adopted here, we subscribe to the tradition of scientific discovery advanced by Popper (1968/1935) and augmented by Lakatos (1978). Falsification is the critical foundation of this tradition but according to Lakatos (1978, p. 35), "No experiment, experimental report, observation statement or well-corroborated low-level falsifying hypothesis alone can lead to falsification. There is no falsification before the emergence of a better theory." The scheme advocated by Lakatos, sophisticated methodological falsificationism, requires series of related theories, where each is an improvement on the one before according to strict methodological criteria.

10. Our concern, therefore, is not in detecting counter-examples and exceptions, but in producing better general explanations. But doing this within the social sciences is especially complicated because, unlike the physical and biological sciences, the social sciences suffer from extraordinary sources of uncertainty. Most variables studied in the social sciences are elastic, that is, they can shrink or stretch under what might appear to be identical conditions. Motivation is one such variable. The amount of motivation that an individual demonstrates is as much a product of complex emotional factors as it is of

externally controlled factors. A second source of uncertainty is alterability. Teacher expectations for student performance, for example, probably had one level of potency or explanatory power before the Pygmalion in the Classroom studies (Rosenthal & Jacobson, 1992/1968), and a different power after the results of these studies were incorporated into pre-service courses. That is, an effect that some people felt had great potency for predicting student changes lost its potency once teachers became aware of it. A third source of uncertainty is fuzziness. Variables such as motivation, self-image, engagement, and independence (as in independent study) lack precision and therefore are difficult to define and to measure precisely. Even fuzzy logic may demand more precision than can be mustered for many educational constructs[3]. These extraordinary factors, coupled with the intrinsic complexity of social systems, as measured either in numbers of variables involved or in difficulty of measuring these variables, make theory building in the social sciences hazardous.

11. Nevertheless, researchers in the social sciences do build theories, beginning with observations and proceeding through ever more rigorous cycles of hypothesis building, data collection, and analysis. The present study fits somewhere in the middle zone of such a progression, well beyond exploratory studies but short of strict experimental methods. Its goal is to inform policy formulation through the pursuit of central tendencies, propensities, and relationships that hold with high probability. Our immediate concern is with what most likely will happen under given conditions or, viewed in reverse, what conditions will most likely result in a desired outcome. All of the conclusions we draw will have an assumed background component, a caveat, worded roughly as "Except in unusual circumstances". Exactly how these conclusions are drawn cannot be delineate in algorithmic terms. Weight of evidence is the primary driving force, where evidence is derived through interpretation of the case study reports against a background of national and regional policies and traditions, plus a wider research literature on schooling.

12. At the lowest level of interpretation, results can be reported as simple counts: So many reported success, so many reported failure, and so many were somewhere in between these categories. At a higher level, patterns can be found that account for most of the category memberships: When conditions X, Y, and Z hold, schools report success; when only X and Y hold, schools are between success and failure; otherwise, they report failure. When the conditions X, Y and Z are identical to those that in other situations were associated with educationally important outcomes, the conclusions have external consistency. However, equally valid results could be inconsistent with findings from other studies, leading to a rethinking of both sets of results and perhaps to a more general explanation for both. The challenge of interpretation is to find potentially explanatory conditions without stretching the evidence beyond recognised limits.

13. The 94 reports have been read by the authors of this report, discussed, and in many cases, clarifications and further information sought from the national research teams. Assertions, in the sense of Erickson (1986), were generated and then tested against the evidence available. A draft of this report was then made and circulated among the national teams, a two-day meeting held to discuss reactions, and further drafts generated and circulated. At a minimum, we have agreement with the national research teams on the interpretations drawn from their reports. Even with this procedure, however, the outcomes here represent interpretations of interpretations, where the original interpretations were derived from relatively brief samplings of classrooms, teachers, and other personnel, augmented with a survey and in some cases additional school based materials.

[3] Fuzzy logic originated as a subset of conventional (i.e., Boolean) logic to handle partial truths. More recently it has been applied in expert systems and character recognition programs (Kosko, 1993).

Site selection

14. Each country was encouraged to select 3-6 sites that had successfully implemented an important schooling innovation or had made steady and significant improvements over a relatively short period of time and had also incorporated or were moving strongly toward school wide use of ICT for support of a learning organisation. The highest priority was to be given to sites where ICT and the improvements had been in place for at least two years. By "innovation/improvement" was intended a deliberate plan for school improvement that had a clear starting point and an identifiable set of changes that moved the school forward as a learning organisation. The changes may have been innovative or not and may have been applied gradually over time or concentrated in a shorter time period.

15. A further criterion was that innovations must be school wide, but could relate to curriculum, teaching, staff development, administration, home and community involvement, resources, continuity of learning, or the spatial and temporal components of teaching and learning. Innovations should lead, or have the potential to lead to significant improvements in the quality of education, its costs, or in equity of access. A Site Nomination Form was provided, to be filled out for each nominated site (see Appendix A). Selection of sites required, in some cases, a one-day visit to a short list of sites to determine which were most qualified. It was also suggested, but not required, that a Teacher ICT Practices Survey that was developed for the OECD quasi-experimental study (see Appendix B) be filled out by all teachers at a nominated site as part of the site selection process.

16. We speak here in a rather loose sense of schools as learning organisations, knowing that in almost all countries this is more a vision or desire than a reality. By a learning organisation we mean a structure that can improve itself, learn from its mistakes, and embody in its own structure and its services new knowledge that it acquires (Elmore, 2000; Fullan 1999; Von Krogh, Ichijo, & Nonaka, 2000). For this to occur, leadership, usually by the principal, must foster collaboration so that teachers are as concerned with the progress of other teachers and the school as an organisation as they are with their own success. Continuous refinements, both communal and individual, are required, a modus operandi that contrasts with national reforms and other top-down changes that are more characterised by sporadic impulse functions than by ongoing, systematic monitoring and improvement. In a concluding section we return to the issue of schools as learning organisations and in particular to how ICT can facilitate this concept.

17. Although the reports and follow up information obtained indicate compliance in most cases with the formal site selection criteria, not all countries followed them exactly. In Germany the process was strongly driven by the agreed criteria. Starting with a national list of all schools connected to the Internet, priority listings were made, reviewed, and eventually pruned through phone calls and site visits. A similar process was followed in the USA where additional criteria were applied to ensure that selected schools had high content standards in core subjects and innovative, technology-supported pedagogical practices. In a few other countries that were also participating in the SITES M2 case studies, a similar requirement for a technology-supported pedagogical innovation was added to the selection criteria[4]. However, in at least one country (Ireland) the list of sites was communicated to the research team by one of the state agencies represented on its steering committee. It appears that site selection here emphasised schools that were relatively rich in ICT resources and were perceived to be using these resources effectively. The research team in this case played no role in the site selection.

18. For policy considerations it is important to keep in mind that the schools reported here are, for the most part, the more successful schools in each country for educational innovation and ICT use. They are not a random sample nor are they just schools with innovative ICT applications or programs. A careful

[4] However, a few countries participating in both the OECD and the SITES M2 studies selected different schools for each study.

reader of the original reports might not agree that all represent successful educational innovation or ICT application; nevertheless, as a group, they represent a remarkable range of schooling innovations and ICT practices. But these schools, on average, are not so privileged, so endowed with resources, and so reflective of upper class advantages that their experiences cannot be applied to the majority of the schools in OECD countries.

Data collection

> "The past is inaccurate because we cannot determine how it was in fact, no matter how hard we try. We must rely on people's memory, which is treacherous, because memory is constantly juggling and revising the data of experience."
>
> Czeslaw Milosz, Milosz's ABC's. Trans. from the Polish by Madeline G. Levine. New York: Farrar, Straus and Groux, 2001, p. 147.

19. To gather a wide variety of data in a limited amount of time (generally one to two weeks of field work per case), data collection was focused on (1) interviews with teachers, administrators, students, parents, and technology specialists, along with (where feasible) knowledgeable people outside of the school; (2) observations of school functioning; (3) collection of student and teacher work and of school documents, including electronic materials; and (4) a survey of teacher ICT practices.

20. Selection of specific targets for data collection varied according to the type of site under study and its organisation but in all cases the collection of multiple perspectives was encouraged. For example, the guidelines for interviewing suggested selection of four teachers, along with at least two administrative staff members, four students, two parents (where relevant), and a technology specialist, if one existed. Among the teachers, half were to be selected from those who were close to or a part of the change process and half from those more distant from the process. (These numbers were based on an assumption of a single school site with a teaching staff of approximately 30 and a student enrolment of about 450. Adjustments were to be made for sites that were significantly larger but not for those that were smaller.)

21. A further consideration was that in examining schooling innovations, outside observers are often guided exclusively to the committed, enthusiastic supporters of the change. These are the people who most likely were closely involved with originating and shepherding the change and who now play special roles within the school, such as advisors, trainers, or the like. Similarly, if you ask teachers for students to interview, the teachers will most likely give you highly verbal students who support what the school is doing. Research teams were encouraged, therefore, to choose interviewees randomly, where appropriate, drawing from groups based on acceptance/rejection of the change, early/late adoption, novice/experienced, or other relevant dimensions. Similarly, teachers and school administrators, because of their exposure to public view and public opinion, are often careful to avoid stating opinions or reporting conditions that differ widely from what is mandated, required, or publicly desired. In examining issues that are potentially sensitive, such as the degree of support for a particular innovation, interviewers were to probe beneath the surface to the degree possible.

22. For all significant issues, triangulation was strongly recommended. That is, wherever possible, data were to be collected not only to give multiple perspectives but also to give multiple types of information that could provide convergent evidence on an issue. For example, in attempting to uncover how much actual use teachers make of e-mail, direct questions to teachers might be coupled with observation of the length of time required for teachers to respond to e-mail messages sent to them by interviewers and statements from parents and teachers on whether or not they communicate with teachers by e-mail, and if so, how effective this mode of communication is.

Main issues in the study

23. The questions that drove data collection centred on uncovering the history and effectiveness of the innovation, establishing its relationship to ICT, determining what components of the school infrastructure were critical for ICT to succeed, and determining the history and consequences of ICT use and whether it was sustainable and scalable. Stated in hypothesis form, these issues were reduced to the following five conjectures, applied to a school or other educational organisation:

a) Catalyst for reform. Technology is a strong catalyst for educational innovation and improvement, especially when the World Wide Web is involved. The rival hypothesis is that where true school-wide improvement is found, technology served only as an additional resource and not as a catalyst, that the forces that drove the improvements also drove the application of technology to specific educational problems.

b) Diffusion of ICT. The diffusion of ICT followed the traditional diffusion pattern for innovations, as outlined by Rogers (1995). The rival hypothesis is that technology functions differently from traditional innovations and that therefore different diffusion patterns occur.

c) Successful Implementation of ICT. Successful implementation of ICT depends mostly upon staff competence in the integration of ICT into instruction and learning. This hypothesis assumes that teachers mediate ICT applications when they are successful, and that ICT's academic value relates positively to teacher competence. The rival hypothesis is that the school technological infrastructure and student ICT competence rather than staff competence determine ICT implementation outcomes.

d) Equity. Gaps in academic performance between high and low poverty students will not increase when all students have equal access to ICT. The rival hypothesis is that equal access to ICT will lead to more advantaged students increasing the performance gap with disadvantaged (high poverty) students.

e) Academic standards. Successful implementation of ICT will lead to the same or higher academic standards in spite of the low quality of many ICT materials. Academic standards are a function of teacher and school expectations and not of the standards of textbooks, ICT materials, and the like. The alternative hypothesis is that ICT use will lead to a lowering of academic standards as students spend more time on marginally beneficial searches and on poor quality Web and courseware content.

24. In addition to these hypotheses or conjectures, we also asked research teams to report on other issues, including gender differences in student ICT attitudes and usage patterns, ICT applications in the school, professional development, and any undesirable outcomes of ICT use that might have been detected.

25. In the original design of the study we attempted to distinguish the school innovation, which is defined in terms of conventional schooling processes and outcomes: improving student achievement, creating a learning environment, involving parents more in their children's academic work, and so on, and the role that ICT plays in realising this innovation. ICT was not seen originally as an innovation, even though we assumed that most sites studied would be doing innovative work with ICT. The only exception we foresaw was when the innovation is concerned with the teaching of ICT skills. Just as schools in the past have attempted to improve their teaching of science or language skills, schools now might have similar ambitions for ICT skills.

26. This distinction appeared to be critical for determining whether an innovation has been successful. If, for example, a school set out to improve its teaching of science, using computers and the Internet to simulate certain laboratory exercises, successful implementation of science simulations by computer would not be an adequate indicator of success of the innovation. Instead we would expect objective measures of science performance by the students, through school or regional standards, or some

other criterion for adequate outcomes. We assume, furthermore, that to achieve true improvement of science teaching, more than ICT must be involved. Staff development, for example, most likely is required, along with, in many cases, a revised curriculum and new assessment methods.

27. As solid as this reasoning might appear by Aristotelian standards, the reality from the field did not allow it to prevail. In a few cases, vocational or technical high schools set out to become ICT focused; in other cases, national or regional requirements specified the integration of ICT into the curriculum. And in one case, Web sites were used as an approach to bringing students and teachers together in collaborative enterprises. In some of these cases, a non-ICT schooling goal can be identified: more student-centred teaching, shifting the curriculum to meet the needs of high-tech employment, etc. but this was not always possible.

MAJOR FINDINGS

> "The first sentence of every novel should be: 'Trust me. This will take time but there is order here, very faint, very human."
>
> Michael Ondaatje, In the Skin of the Lion. Toronto: Penguin Books, 1987, p. 146.

Catalyst for reform

28. The central finding of this study is that ICT rarely acts as a catalyst by itself for schooling change yet can be a powerful lever for realising planned educational innovations. Exactly what this conclusion means for policy and how it was derived will be developed over the following pages. To begin, we clarify what we mean by *catalyst* and by *lever*. GR01-School A[5] is a medium size, private primary school (grades 1-6) on the northern outskirts of Athens, drawing its students from relatively affluent homes. Over 15 years ago it introduced ICT as part of an effort to improve student thinking skills. According to the current sub-headmaster, ICT use led to collaborative work among students, which then led to the teachers deciding to change their way of teaching. Students, as result of ICT, now work more autonomously. If group work and student autonomy were not major objectives in the original introduction of ICT, but had resulted nevertheless, then we would view ICT as a catalyst for them. However, a university-based expert group that led and supported the ICT implementation explicitly built these objectives into its plans and guided the teachers toward these ends. Although an outside observer might conclude that group work and student autonomy happened by themselves as a result of the ICT implementation, closer examination reveals that ICT was used as a lever to bring about these changes.

29. More common were cases like PT02-Póvoa do Lanhoso, a large public high school (grades 7-12) in a small town in Portugal, drawing many of its students from poor and less educated homes. As a result of the opportunities offered by a Ministry of Education Internet program, the school management body set out to introduce a new curriculum and new teaching and learning methods based on ICT. That is, the management team recognised the potential that ICT had as a lever for curricular and instructional change, both of which were original goals. Similarly, in IL03-Neot David, a large religious elementary school (grades 3-6) in a metropolitan area near Tel Aviv, ICT was used as a lever by the principal and teachers to create learning communities for teachers and students. The long-term goal was to develop independent learners, with learning communities one of the organisational mechanisms adopted for this end. According to the report, "The principal … chose ICT as a lever for the development and growth of the school".

30. Similar to PT02- Póvoa do Lanhoso and IL03-Neot David is JP01-Utase, a new junior high school in a newly constructed city in Japan, Chiba City. Radical departures from traditional Japanese

[5] In this summary the various reports are referenced by their report codes, which consist of a two-letter country code based on Internet country addresses, plus a sequence number (e.g., AT05-Graz-Webling). A complete list of such codes, along with the general characteristics of the indicated schools, is included in Appendices C.

educational procedures were instituted when the school was built in 1996 as steps toward encouraging students to be more creative and independent thinkers and learners. Instead of students remaining in their rooms for each class period they circulated, with teachers remaining in the classes. Uniforms for students were eliminated as were the bells announcing the beginning and end of each class period. Subject centres were created, with open work spaces and computers, printers, and projection equipment to facilitate information access and presentation. ICT was an integral part of the school planning but clear educational goals and strategies were evident from the beginning, with ICT playing a strong support role.

Catalyst vs. lever

31. A *catalyst*, as used here, is an agent that provokes or instigates change. An example familiar to almost all is the movable type printing press that was introduced in Western Europe in the middle of the 15th century and over a relatively short time spread across the Continent. Its invention was a response to an overwhelming demand for the copying of books, yet in time its use led to major alterations in the ways in which data were collected, stored and retrieved, how communications were carried out among the learned, and to other changes that altered scholarship, administration, commerce, and everyday life. One of the major works that explores this revolution in detail is titled *The Printing Press as Agent of Change* (Eisenstein, 1979)[6]. Another familiar example is the automobile, developed to speed transportation, yet acting as an agent for revolutionary changes in urban design, family relationships, commerce, and even sexual behaviour (Bell, 1976; Lynd & Lynd, 1929).

32. A lever, in contrast, is not an agent but a tool. It must be applied purposefully to a task to be of value and cannot, except in exceptional chain reactions, have far-reaching consequences. An agent, once introduced, can act beyond its immediate goal, causing significant change; a lever can only be applied to achieve an intended goal. (It can, of course, slip and do unexpected damage or be used recklessly but these are not defining characteristics.)

33. The distinction we make is critical for policy. If the mere application of ICT within a school generally led to more student centred teaching, then countries that desired changes in that direction could focus resources solely on bringing a strong ICT infrastructure into schools and assuring that teachers used it in their teaching. The opposite finding, which is what we are reporting, leads to a different strategy wherein both the ICT infrastructure and the planning and professional development for pedagogical change are required to achieve more student centred teaching. However, ICT can act as a lever for change, providing a strong push toward innovative practices, but the direction of change must be carefully mapped in advance and the staff prepared for it. All of this was summed up concisely in GR03-School C: “One of the teachers mentioned that computer use encouraged new ways of learning, that is, open learning approaches. However, she argued that it was not the computer use per se that encouraged these new learning situations. It was the teacher who aimed to such approaches, facilitated though by the computer use.”

34. In a number of cases where on first reading ICT appeared to be a catalyst for change, we found on more careful examination that it acted not as a catalyst but as a lever. This was true of GR01-School A and of several Austrian cases where schools were facing declining enrolments and in at least one case, declining achievement. In each of the Austrian cases, plans were made for changes in the teaching methods and in the curriculum, using ICT as a curriculum option. In one of the cases (AT05-Graz-Webling), a vocational school modified its programs to emphasise information technology, shifting away

[6] An earlier and equally important work on the impact of printing, Lucien Febvre and Henri-Jean Martin’s L’Apparition du Livre [The Coming of the Book], speaks of the printed book as “one of the most potent agents at the disposal of western civilisation” (Febvre & Martin, 1976/1958, p. 10).

from wood and needle work. Similarly, in a number of the Hungarian cases, ICT courses were required by the National Curriculum and therefore ICT was introduced into the schools, leading to students and teachers becoming ICT literate. For some of these cases, ICT had a symbolic value that helped to change parental attitudes about the schools or that made the school more attractive to staff and students.

35. In other cases, it was difficult to attribute educational changes to the introduction of ICT because the schools were co-operating with research programs or pre-service teacher education institutes that provided professional development and support for specific applications of ICT, along with new approaches to teaching and learning. These include FI02-Oulu, which " supports and complements research activities of the faculty of education [University of Oulu]", FI04-Länsimäki, which is collaborating with the University of Turku on a computer-supported collaborative learning project, MX01-ESANS, which is a pedagogic laboratory for the Superior Normal School (Escuela Normal Superior-ENS) to which it is annexed, JP04-Gifu, which is annexed to the Gifu Normal School, and GR02-School B which is collaborating with the University of Athens on a Logo project.

36. In the rest of the cases, ICT was a support for school improvements that were planned by the school staffs or by a higher administrative body (e.g., national ministry of education). Typical of such cases is IL01-Ohel Shem, a public high school with 1,250 pupils in grades 9-12, where innovative technology was adopted as a "means to create innovative pedagogy". At IE03-Peadar & Pol, ICT was adopted because of its potential to support a new curriculum. In the most typical cases, a school wide improvement or innovation was planned and ICT used as one of several supports for it. In a few of these cases, ICT, once implemented, served as a catalyst for further changes. Two clear examples are AU01-Bendigo and AU02-Glen Waverley, both public high schools in the state of Victoria in Australia. Both schools, in reaction to state educational objectives, decided over the past 3-5 years to shift their curricula to be project based, to emphasise student autonomy in learning, and to shift teaching from teacher centred to teacher guided.

37. Both schools developed intranets for staff communications, for submission of student work, and for student learning, and both staffs have contributed subject area lessons and support materials to their on-line systems. In both cases school management and teacher planning teams set teaching and learning goals for their schools, considering changes needed for administrators, teachers, and students. The potential of ICT was probably a factor in some decisions but the primary emphasis on student autonomy was an academic decision, not one driven or catalysed by ICT. But ICT, once integrated into the lives of these schools, opened further opportunities for innovation and change. A staff member at AU01-Bendigo recalled that "I also think the way I experimented with the technology in those early days actually influenced my teaching. I learned the value of discovering things for yourself through that experience and I encourage the students to behave like that now". Similar findings were reported from DK03-Kerby and DK04-Rugkobbel, where the process of implementing ICT became a catalyst for other school changes.

38. At MX03-Santa Maria, a high school computer network was developed as part of a community-based program that included high school education, community development, and craftsmen training. The community, located in a remote rural area, created a global view of knowledge that was congruent with local cultural values, including cosmogony, language, and dress. Once installed, the network, even with limited weekly use by each student, led to students accessing a wider selection of knowledge resources than ever before and pursuing knowledge more independently. The computer network, although essential for promoting a global view of knowledge, was a support tool for the broader project.

39. Another representative case of ICT as a support for innovation is IT03-Rodari, a primary school (ages 6-10) in northern Italy (Udine). The school has for many years emphasised communication in its curriculum and searched for innovative ways to involve students more in communicative processes. One teacher, quite by accident, began encouraging students to write their comments on specific topics on little

slips of paper and to pin these to a notice board for others to read and respond to. Soon the comments were being done by computer and shared with other schools via an early computer interconnection system (Fidonet). In time this led to a school Web site, to participation in various international communications projects (e.g., KidsLink), and to regular use by students of computer communications. The research team sees ICT as a support for making learning more fun, with communication still a major school focus. Over time teaching has become more student centred and the classroom has become connected to the rest of the world.

40. One might ask, in spite of the evidence cited here, "Shouldn't ICT prompt new ways of teaching? Isn't ICT such an innovation itself that the very act of using it for teaching causes new and different approaches to instruction?" What is forgotten in such an argument is that the very power of ICT is its flexibility, its adaptability to any set of sequential procedures, which means that it can be adapted as easily to support teacher centred instruction as it can for student centred. The summary to the Norwegian reports made this point succinctly. "Further, we can state that ICT can support traditional academic didactics as well as a project- and problem-based perspective. ICT does not have any structural properties that does not make sequence-oriented academic teaching not suited for this media--the fact is quite on the contrary" (NO00-Summary). To supplement this point and to complete the discussion of ICT and its relation to innovation, we review in the following sections the ICT applications and the innovations reported by the schools involved.

ICT applications

41. Even with limitations due to equipment and technical support, an impressive array of ICT applications were reported. The most fully developed systems, almost always found at the secondary level or above, had functioning intranets where teachers displayed course syllabi, problem sets, and the like and students stored and submitted home work, accessed the World Wide Web, e-mail, and other resources, and displayed their own home pages.[7] Among the schools that described such projects were AU01-Bendigo and AU02-Glen Waverley, DK03-Kerby and DK04-Rugkobbel, LU01-Athenee and LU02-Biever, FI02-Aurora, IT03-Rodari and IT04-Tosi, NL01-De Verrekijker, SG01-School 1, SG02-School 2, and SG03-School 3, and US04-Pine City. SG01-School 1 has, perhaps, the largest array of resources available on such a system, including, besides the items described above, recorded lectures and lecture notes, past examinations, and group discussions. NL01-De Verrekijker and US04-Pine City, among a few others, provide information for parents on their Web sites; other schools have connected their local communities, including businesses, libraries, and civic organisations.

42. Universal across the schools was the use of tools (often called "open tools"): word processors, spread sheets, graphing and drawing programs, search engines, and presentation programs such as Powerpoint. Web design tools and other hypertext generators were occasionally mentioned (e.g., AT02-Grein, IT02-Lepido). Surprisingly absent from most lists were database programs (e.g., FileMaker Pro, mySQL). Either the limited database capabilities of spread sheets are used or teachers (and ICT curricula) are not including the study or use of one of the most fundamental tools for information handling[8]. E-mail

[7] An intranet is a network that allows shared access within an organisation to databases and communications through WWW protocols and software (along with access out to the Internet) but blocks access from the outside. Some of what were reported as intranets were, technically, extranets because they allowed access from the outside through password control.

[8] One exception to this vacuum was KO01-Banghwa where a student records database was developed on-line for counselling. However, this was not available to students and was not used in instruction. In addition, two technical schools in Italy (IT01-Einstein, IT04-Tosi) listed databases in their curricula for ICT courses.

was widely mentioned although a few schools still have no e-mail accounts for students or teachers (e.g., AT01-Steinbau). Other applications included forums, chats, simulations, videoconferencing, Logo, and traditional CAI. Usage patterns varied considerably, however. US03-Mountain reported that about 75% of all software used by students and teachers was tools, while UK01-Greenfield reported more extensive use of educational software across all of the national curriculum subjects, as did NL02-Marke.

43. The ICT applications that transformed schooling the most involved advanced communications, bringing together different partners in the delivery of instruction, creating communities centred around the schools, and delivering materials and instruction on an anytime/anywhere basis. Few schools reported cutting edge applications of ICT to instruction such as intelligent tutors, expert diagnostic systems, or simulations. One reason for the absence of these latter applications is the lack of enough high power computers within a class or school to allow all students to have on-going access to courseware or the Internet at the same time. A second is that few such applications are available to schools, especially in languages other than English. A further problem, which we can only speculate on here, is that the cutting edge tutoring systems, simulations, and the like were not designed adequately for teachers to use them as a resource in their teaching.

Innovations and their origins.

> "What a novel idea, Don't you believe it, Sir, King Solomon, who lived such a long time ago, affirmed even then, that there is nothing new under the sun …"
>
> José Saramago, História do Cerco de Lisboa [The History of the Siege of Lisbon]. Trans. From the Portuguese by Giovanni Pontiero. San Diego, CA (USA): Harcourt Brace, 1996, p. 7.

44. Innovations rarely exist on their own. Except in those few cases where innovation is the mother of necessity, that is, where a process, a method, an object is invented and then leads to the discovery of uses for it, innovations arise in response to human needs. In schooling, in particular, problems emerge that require solutions. Where systematic problem solving procedures are applied, goals are established, along with strategies for reaching these goals, and then tactics for implementing the strategies are selected or generated, sometimes guided by general school principles or philosophies. US06-Joshua Junior High School in the USA presents a clear case of this sequence. "In the district, including at Joshua Junior High, their stated purpose for technology integration is to raise student achievement; their pedagogical approach for doing so is to focus on technology as a support to Inquiry-based instruction."

45. In this case, the problem to be solved was lower than desired student achievement. The pedagogical strategy selected for raising student achievement was Inquiry-based instruction, and one of the tactics was to use technology to support this strategy. Within the report further information is given on the implementation of this tactic- creating an ICT infrastructure, including staff development for ICT, planning for integrating ICT in the curriculum, reallocation of a portion of the district budget for wiring and other technological needs, and so on. Technology is neither the innovation here nor is it the primary strategy for solving the school's problems. As the report states, it is a "support to Inquiry-based instruction".

46. AT02-Grein, a junior high school in Austria, represents a slightly different situation because enrolment as well as academic performance had been declining at the school. To deal with these problems, both of which threatened the existence of the school, the school management decided that the school needed a new academic profile. The strategy for creating this new profile was to make ICT instruction a major focus of the school's academic program. A special ICT track was created, including typing at the 6th grade to prepare students for heavy computer use, and even an optional computer sciences course. At AT02-Grein, ICT was a central component of the strategy for problem solving. The assumption was that

parents would want to ensure that their children were prepared for a digital world and would, therefore, want to enrol them in a school that had a highly visible (and academically sound) ICT program.

47. In NO01-Ringstabekk, the school goals derived from an accepted ideology that valued constant staff experimentation and creativity and strove for helping students to learn and work co-operatively. When faced with student learning problems that appeared to derive from a lack of context for learning, the staff shifted instruction and learning to a problem-based approach, with team learning and close involvement of businesses, local trades, and community. Learning was organised around contextualised, ill-structured problems, with ICT as a major tool for problem definition, solution, and presentation.

48. At DE03-Albani, a decision to become a 100% Half-day School (Volle Halbtagsschule) required staff agreement on an educational focus for the school. Discussions initially favoured Montessori methods but disagreements among some of the staff and a general feeling of dissatisfaction with existing school structures forced a re-evaluation of the school's problems, from which emerged a plan for inter-cultural education. Shortly thereafter, an opportunity to become an EXPO school at the World Exhibition 2000 in Hanover led to the addition of ICT as an enabling element for this emphasis.

49. As a final example, we turn to a case where multiple strategies were adopted to solve a more general problem. The case is FR01-Marie Curie, a new (est. 1990), large high school south of Grenoble in France. The strategies for improvement, that is the innovations, derived from a desire by the school management and teachers there to adapt instruction and the school environment to the needs of higher education and the working world. Although the school was established as an experiment in ICT and pedagogy, with a computer network in place on opening, the five themes in the improvement strategy all relate to non-ICT goals: quality of school life, tutoring, group work, diversified training, and connecting to the community. Once again, ICT was a support for the implementation of some of these themes, playing a large role in connecting the school to the community but a lesser role in the work of the two tutors assigned to each class.

Problems schools face

50. All of the innovations in the case studies arose as components of strategies for solving schooling problems. Across all of the cases the problems can be classed in a small number of categories. (The ordering here is not by magnitude or importance but roughly from the most general to the most specific.)

a) School survival. It is probably the case that this is, as with all other organisations, the long-term, ultimate goal that drives the day by day existence of schools. Where enrolments are based on defined catchment areas, the threat to a school's existence is relatively weak. However, even under such conditions, low birth rates without replacement through immigration, new housing developments, or other means can lead to declining school enrolments and to school closings. Where parents have wide options for where to enrol their children, the threat is more visible and pressing.

b) Student achievement. Low student achievement, surprisingly, is not mentioned often as a major schooling problem, but it does occur in a few European and in most of the USA cases.

c) Independent learning. Student ability to learn independently—to recognise learning needs, select learning goals, schedule time, monitor one's understanding, etc.-- is often mentioned, particularly by secondary schools.

d) Preparation for work. Preparation for or transition to work occurs mostly at the secondary level and for both vocational/technical schools and for comprehensive high schools.

e) ICT abilities. Student ICT skills are mentioned in a number of reports as the primary problem that drives the need for change. In many of these cases, the need is created at a central level (e.g., at a Ministry of Education). More often, ICT skill instruction is a strategy for ensuring that students are prepared for a digital world, including work.

Strategies for solving problems

51. The issues just mentioned relate to the primary goals of schooling, that is, the reasons for having schools in the first place. Later we will present tactical problems that schools need to solve to implement specific solutions for these problems: budget, staff development, rigid national curricula or examinations, space, etc. These are all operational issues as opposed to essential goals of schooling. The means or strategies employed to solve the set of problems just presented also cluster in a small number of categories where improvements or innovations could be made.

a) Curriculum change or enhancement. This might appear as alternative tracks for learners (e.g., a bilingual program), revision of a specific academic subject such as science, the addition of an ICT track or concentration or inter-disciplinary projects.

b) Improved access to learning. Distance education, web-based learning, and other approaches for achieving anytime, anywhere learning are the primary examples of this category. We include here, also, other extensions of the classroom such as connecting it to wider communities of interest: homes, local community, schools in other regions and countries, tutors and mentors, and other support services.

c) New teaching/learning methods. Constructivist approaches (student-centred learning, teacher facilitated learning, etc.), theme or project based teaching, collaborative learning, tutoring and mentoring, and improved instructional management, including Flexible Curriculum Management and student monitoring.

d) Reform of school organisation. Among the innovations in this category are micro schools and other forms of schools within schools, looping, flexible scheduling, shifts from hierarchical to more horizontal structures, and study houses and centres.

e) Improved staff support. The creation of a school intranet to promote a professional community for a school staff, the provision of instructional tools and materials electronically, and the use of distance learning for staff development all are staff support strategies.

52. In many cases the innovations originated at the school level; in other cases the innovations derived from programs or directives from a regional or national level, or in the case of European Union programs such as Comenius, from a cross-national level. In some cases there are multiple innovations or the innovations merge with goals and strategies.

Summary

53. As Pasteur noted long ago, “In the fields of observation, chance favours only the prepared mind.” So does ICT favour the prepared organisation. No miracles derive from the mere presence of ICT in a school; it does not, except in unusual circumstances, act as a catalyst for wide scale improvements. Instead, ICT can be a powerful lever for change when new directions are carefully planned, staff and

support systems prepared, and resources for implementation and maintenance provided. Unlike other levers available to schools, however, ICT has the power to facilitate vast changes in instruction, in home, community, and school relations, and in school management. It should not be viewed as a simple tool, to be considered only after changes are planned, but as a more powerful ally that can help schools aspire to and reach the highest goals of education. Furthermore, once reform with ICT is implemented, a climate for innovation may remain wherein ICT can act as a catalyst for further changes.

Diffusion of ICT within a school

> "In fact, even the early Middle Ages … were a period of incredible intellectual vitality, of impassioned dialogue among barbarian civilizations, Roman heritage, and Christian-Eastern elements, a time of journeys and encounters, when Irish monks crossed Europe spreading ideas, encouraging reading, encouraging foolishness of every description." Umberto Eco, Travels in Hyperreality. Trans. from the Italian by William Weaver. San Diego, CA: Harcourt Brace Jovanovich, 1986, p. 75.

54. The policies and procedures that lead to a school staff's adoption of ICT are of especial interest for policy formation, given the critical role that teachers play in the integration of ICT into the curriculum. Schools are loosely coupled systems wherein each level maintains considerable autonomy (Weick,1976). A ministry of education or a municipal or regional equivalent can request or require teachers to teach in specified ways but this will not guarantee that they, in fact, behave as desired. The school principal will attempt to enforce such an administrative request with greater or lesser enthusiasm and teachers will demonstrate the same variability in following the directions of the principal. Thus, it is important to understand how innovations in education come to be adopted or rejected by teachers[9].

55. Research on this topic has been summarised by Rogers (1995), who has contributed a widely accepted conceptual framework for the issue. The starting point for Rogers (1995) is to view organisations (including schools) as social systems composed of individuals with varying degrees of openness to technological innovations. The rate at which an innovation is adopted within an organisation is a function of certain characteristics of the organisation staff, the innovation, and the information disseminated about it. For example, an innovation will be adopted more quickly if the potential adopters are convinced that there is a relative advantage to such behaviour and if the innovation is compatible with the adopters' current practices and values. Rogers (1995) divides potential adopters into five categories, based upon socio-economic status, communication behaviours, and personality values: Innovators, Early Adopters, Early Majority, Late Majority, and Laggards. Change agents can affect adoption decisions positively by providing knowledge and training and by reassuring potential adopters that an innovation will meet their needs.

56. Fullan (1999, 2001), who has written extensively on school change, has treated diffusion by focusing on the conditions that foster large-scale reform grounded in local ownership. Central to his concerns are whether the people most affected by a change can find meaning in it. In a recent updating of his views on adoption of reform, Fullan (1999) has emphasised complexity, conflict and diversity, uncertainty, and multiple theories of change. He sees fragmentation and overload as the biggest problems that schools face.

[9] Although diffusion among administrators is of equal interest, too few cases are reported here of administrator adoption for generalisations to be made.

Traditional diffusion pattern

57. The present study did not attempt to probe the adoption process beyond finding if the traditional diffusion pattern, as defined by Rogers (1995), had occurred for ICT. In its simplest form, the traditional pattern is characterised by a small group of Innovators (the first 2.5% to adopt), a larger group of Early Adopters (the next 13.5% to adopt), an even larger group of Early Majority (the next 34%), and so on. We did not ask for such quantitative definitions, only for general trends. The results show that the traditional diffusion pattern held in most cases. The exceptions, such as GR01-School A, were cases in which schools had been built recently as high-intensity ICT sites, with selection of staff in part according to their ICT abilities or willingness to engage in intensive ICT training, or where other internal or external pressures gave teachers no alternatives but to accept ICT as part of their teaching.

58. A typical case of diffusion can be found in LU02-Biever, a technical high school in Luxembourg with a high (about 33%) foreign student enrolment. The Innovators were a small group of mostly male mathematics and science teachers, motivated in the 1980s by an interest in computer programming. Once Microsoft Windows became available, along with good word processing programs, a wider group of teachers, including language teachers, began to use the school computers. This group of Early Adopters included both males and females across a wide age range. Internet access in the mid 1990s was an incentive for a larger group of teachers to become computer users (Early Majority). Today 70-80% of the teachers use ICT either for preparing their own work or within classroom instruction. The Laggards are either deterred by technical problems or are not yet convinced of the value of ICT in teaching and learning or are reluctant to invest time and effort in ICT without more convenient student access within the school to ICT for general courses. Similar cases were reported for three of the Irish schools where initial change agents with high commitment and enthusiasm attracting other teachers to exploring ICT.

59. An apparent exception to the traditional diffusion pattern occurred at NL01-De Verrekijker, a small primary school (K-6) in the south of the Netherlands. This school has only 15 teachers, four of whom have shared jobs. The technology co-ordinator developed an ICT plan that the entire teaching staff enthusiastically endorsed. Personal use of computers and the Internet was taught first to the staff, followed by instructional use training. Through this procedure, every teacher became a user, accessing the school intranet from home, using their home computers to prepare lessons and write activity plans, and assigning software in conjunction with their textbook assignments.

60. The small size of the school, the adeptness of the technology co-ordinator, the school ICT infrastructure, and the provision of computer software within textbooks all contributed to the rapid diffusion of adoption. However, whether this is an exception to the traditional diffusion pattern or a case of rapid, traditional diffusion is debatable.

61. Some teachers did show a "hesitance to work with technical devices" and even after all teachers had earned their European Computer Driving Licence (ECDL)[10], some still had problems using ICT in their teaching. Although all teachers apparently used ICT in preparing their lessons and were users of the Student Monitoring System or of other ICT-based resources, only 3 of the 13 teachers responding to the ICT Practices Survey rated their ability to use a computer as "good." All the others responded with "fair".[11]

[10] The ECDL (Version 3.0) has seven modules, covering basic concepts of ICT and different applications: word processing, spreadsheets, databases, etc. A description of the syllabus can be located at www.ecdl.com/syllabus/index.html.

[11] We cannot rule out the possibility that these self ratings may reflect a high degree of modesty: teachers may equate "good" with "expert" and therefore choose "fair" to describe their own abilities.

62. That a small teaching staff does not invariably lead to rapid and non-traditional diffusion of ICT is demonstrated by UK03-Littlejohn, a small elementary school (ages 7-11) located in a low socio-economic area on the edge of a major city in the UK. Even with only eight full-time teachers in the school, there was a single Innovator (the head teacher), a small group of Early Adopters, and a few resisters initially. A laptop strategy, using more experienced ICT users to help train and mentor the novices, was spread over three years. Today all of the teachers have been trained and are ICT users.

Acquisition vs. deployment.

63. So far in this discussion we have presented a simplified view of diffusion, with no clear statement about what is diffused and what indicates completion of diffusion. Some research on diffusion distinguishes between acquisition of an innovation and its deployment (e.g., Fichman & Kemerer, 1999). In NL01- De Verrekijker, for example, the technology co-ordinator first taught the staff personal use of ICT and then educational uses. For the most part, however, little professional development was devoted to integrating ICT into instruction. Therefore, early in the ICT project ICT skills were widely distributed among the staff but deployment was limited. IE01-St. Joan's is typical of many schools in reporting that a high percentage of its teachers were competent in ICT skills but a lower percentage were competent in integrating ICT into teaching. A comparable situation occurs when professional development is successful but the school ICT infrastructure limits the application of these skills. Fichman and Kemerer (1999) point out a number of examples in the USA where a technology was widely deployed but with limited utilisation, including computer-aided design (CAD) in the 1980s. If the gap between acquisition and deployment is large, using acquisition for diffusion modelling or for policy decisions can give false predictions of future use.

64. For the diffusion of ICT within a school, the research literature is somewhat divided on what is being diffused or adopted. In the early phases of the Apple Classroom of Tomorrow (ACOT) project, the developers assumed that teachers needed only to learn how to use the technology and how to recognise the best of available educational software. Thus, basic technology skills and software evaluation procedures were stressed. In time, the failure of this approach led to a shift in emphasis to applications that supported collaborative learning and project-based knowledge construction (Yocam, 1996). With this shift, diffusion was centred on changes in teaching styles. In contrast, DK02-Korinth uses ICT "primarily … as a tool for systematic diffusion of knowledge". This innovation is widely diffused among the staff but as yet involves limited integration into teaching. Nevertheless, teachers' work habits have changed as they now can remain in communication with other teachers, students, and parents from outside of the school. In addition, the school uses its homepage to recruit new students and to retain graduates within the school community.

65. Thus, diffusion could refer to ICT competencies of teachers, to teacher classroom practices with ICT, or to the use of ICT to maintain relationships across staff, students, parents, and community members. The Danish Summary Report (DK00-Summary) further separated diffusion into the organisational structure of a school from diffusion into the pedagogical structure. For this study, we accept each school's own goals for ICT as a basis for analysing the rate and manner of diffusion but in general are concerned with the use of ICT within a school for innovative administrative or pedagogical ends rather than simply as a tool such as for student records or for preparation of teaching materials. This does not eliminate observing and reporting on expansions in the use of ICT that stretch beyond original implementation plans; however, it does reject any particular belief about what constitutes the ultimate process of classroom learning or of organisational behaviour.

66. Related to what is diffused is the issue of when diffusion is complete. The classical studies of diffusion generally involved complete or nearly complete adoption by a designated group. In Carlson's (1965) study of the adoption of modern math in the Pittsburgh area (USA), 100% of the principals

surveyed adopted the approach within a five-year period. In Ryan and Gross's (1943) study of farmers and the adoption of hybrid seed corn, 257 out of 259 farmers adopted the new seed within the study period. Rogers (1995, p. 399) defines completion in terms of routinization: "Routinization ocurs when the innovation has become incorporated into the regular activities of the organization, and the innovation loses its separate identity. At that point, the innovation process in an organization is complete". Fichman and Kemerer (1999) present a slightly vaguer definition of completion, basing it on saturation within the population of potential adopters, without defining what qualifies as saturation. For the present we accept the routinization definition for completion because (1) it derives from the system behaviour of the entire school, (2) it can be operationalised (although we do not attempt to define how), and (3) it does not require 100% compliance on the part of a teaching or administrative staff.

67. Where the primary goal of introducing ICT within a school is to encourage and support innovative teaching practices, stage models offer some assistance in gauging degree of ICT diffusion. One example is provided by Mandinach and Cline (1994), who have extended a model derived from the ACOT studies to include four stages of diffusion: survival, mastery, impact, and innovation. In the survival stage, teachers struggle to learn the technology, operating mostly by trial and error while maintaining the status quo in their classrooms. As technical competence increases, the mastery stage is reached in which new forms of interactions are developed, along with better coping strategies, sounder curriculum models, and less reliance on systems experts. In the impact stage, the classroom becomes more learner centred, technology becomes infused in learning activities, and use of systems applications becomes more varied. Finally (for some teachers) the innovation stage is reached, wherein the teacher restructures the curriculum and learning activities, moving beyond the mandated procedures and content. This model offers a perspective for evaluating the diffusion of ICT within a school when change in classroom practices toward a learner-centred classroom is a prime objective. By these standards, few if any of the cases reported here have reached the innovation stage.

68. From a cross-national perspective, the diffusion research helps in discerning commonalties across disparate educational systems. Nevertheless, for many of the schools reported in this study teachers were not independent agents who could act according to their own judgments, competencies and beliefs, as could the farmers studied by Ryan and Gross (1943) or the administrators studied by Carlson (1965). Nor were internal factors always the most important ones for diffusion. Instead, external factors often acted as positive or negative forces for ICT adoption. The Irish upper secondary schools are typical of many throughout the OECD countries where national examination requirements drive teaching and learning. In almost all of these cases, ICT is not covered by the examinations and therefore teachers are not apt to spend much effort on it. In contrast, for a primary school in Ireland, IE01- St. Joan's, "The innovation was driven by external forces and the staff had no option but to accept ICT as a major part of school policy" (IE01-St. Joan's). Similar situations were reported for other countries, including Hungary (HU01-ASE) and Korea (KO01-Banghwan).

69. Because schools are loosely coupled systems, forces acting upon teachers do not propagate equally. A directive from a national authority to include ICT instruction across the curriculum, if not accompanied by funding for professional development and infrastructure and if not embedded within operational policy, will have less impact than the specified content of national examinations if these have important consequences. Given the interests of parents, communities, and administrators in the future of their children and in the reputations of their educational institutions, coupling is often quite tight for high stakes testing. Viewed differently, the loose coupling of educational layers could be described as a mechanism for protecting autonomy at the school and classroom levels. When requests from higher levels are for changes that are not favoured at the school level, they can be muted, delayed, or deflected, but when the need for compliance is convincing, administrators and teachers can respond positively.

Barriers to diffusion

70. Where ICT has not reached saturation within a school staff, three main types of barriers are cited: (1) lack of opportunities for appropriate (i.e., practical) staff development during working hours, (2) teacher resistance due either to personal teaching styles or to negative attitudes toward ICT, and (3) limited infrastructure, including, especially, technical support. The utility of a school ICT infrastructure is a function not only of the equipment, Internet connections, and support available, but also the locations of the computers and the policies that govern computer access. In many countries, concerns about the digital divide have led to a reluctance to assign homework that requires students to access computing outside of the school. Therefore, if the school computers can not support a particular type of ICT based assignment, that assignment will not be made. Across countries and across administrative units within countries, there is little agreement on the amount of ICT required to sustain an ICT-based curriculum. Singapore, for example, is aiming for a student/computer ratio of 2:1 in its schools while the state of Victoria in Australia has recently set a target of 5:1, with the worst case school having no more than 6:1.

71. The UK Laptop Project evaluation put forth the idea of a critical mass of ICT required within a school before ICT can catch on with the staff (Harrison, 1998). This idea is also reiterated in CA02-Mountain View, which speaks of a critical mass of practitioners to create a culture of innovation. We don't have a clear definition of what a critical mass might be for any desired level of ICT involvement but suggest that it be defined by types of usage rather than by simple counts, ratios, and percentages (student/computer ratio, number of classrooms connected to the Internet, etc.). What is needed is an understanding of the types of academic assignments that can be supported by any particular infrastructure. Can, for example, a class of 30 fifth-grade students locate information on specific historical figures on the World Wide Web or take a 25-item multiple choice test on-line, each within four school days? How these questions are answered will be a function of access methods as well as total machines or connections. Six computer labs with 25 multimedia, Internet-connected machines each mean one thing when computer science courses are taught and use 90% of the lab time and something different without such a demand.

72. As with all change procedures, the degree to which those affected most by the change subscribe to it, the faster will the change occur and the more thoroughly will it penetrate into the routines of the organisation. Where agreement among an entire school staff to participate in an ICT implementation was unanimous and where the teachers were actively involved as partners in designating goals and objectives for ICT (e. g., DK03-Kerby, DK04-Rugkobbel), diffusion appeared to occur more rapidly. Such cases rarely occur, however, without adept school leadership.

Summary

73. The adoption of ICT within a school generally followed a traditional pattern for diffusion of innovations. The exceptions were schools that were able to select their teaching staffs at least in part on the basis of ICT abilities or attitudes, or schools where external forces were strong enough to override the normal diffusion pattern. Within any school, acquisition of ICT skills by the teaching staff may not lead to deployment of these skills for teaching. Degree of diffusion, including what is defined as completion of diffusion, depends upon the expected applications of ICT and therefore cannot be universally defined. However, sufficient professional development opportunities and support, compensated time off for training, and an adequate ICT infrastructure present the optimal conditions for advancing the adoption of ICT by a school staff. Diffusion can stall or retreat without appropriate leadership or without the supports just described.

Successful implementation of ICT

> "Furthermore, while firecrackers merely had to make the same satisfying noise over the years, success in the fireworks industry required ever changing novelty, artistry, craftsmanship, marketing, and advancements in technology…"
>
> Warren Dotz, Jack Mingo, & George Moyer, Firecrackers: The Art & History. Berkeley, CA (USA): Ten Speed Press, 2000, p. 19.

74. Hypothesis 3 attempts to probe the within school elements required for successful implementation of ICT, the suggested candidates being staff ICT competence, ICT infrastructure, and student ICT skills. The replies across the 94 case reports, at first glance, offer no consistent pattern. The general situation is reflected at a country level by the Italian reports. IT01-Einstein implicated mainly teacher technical ability and stressed the generally linear relationship found in the teacher survey between teacher technical ability and student use of ICT. IT02-Lepido, in contrast, stressed teacher ability to integrate ICT into the curriculum, while IT03-Rodari focused on teacher pedagogical ability along with technical ability and IT04-Tosi pointed mainly to the ICT infrastructure. A few reports from other countries implicated infrastructure primarily.

" In the long term, it is important that the technical infrastructure really work; otherwise the teachers and IT specialists involved will be frustrated, and no meaningful planning is possible." (AT00-Summary)

"The technology and infrastructure must be reliable, powerful and efficient." (AU00-Summary)

75. LU01-Athenee is a case of a school well equipped with technology but where the teachers are reluctant to integrate it into their teaching. Fear of technical problems and preference for traditional teaching methods are the main reasons mentioned in the report. In the UK, teachers were able to overcome faulty and inadequate technology. "In all three schools, ICT development happened in spite of the technical problems" (UK00-Summary). Similarly, in NO01-Ringstabekk an 18:1 student to computer ratio was deemed insufficient to encourage use by the average teacher. Nevertheless, the most competent teachers did manage some ICT applications. In NL04-Oost 'Learning Space', an application for anytime, anywhere learning, was used by teachers and students despite problems with Kennisnet, a national network for schools that also gives access to the Internet.

Critical level of implementation

76. A first step to sorting out these differences is provided by the Germany reports, which speak of a "critical level" of ICT infrastructure that must be reached before teacher ICT skills can have an impact. This corresponds to the critical mass idea presented in the previous section of this report. A further step derives from several of the Singapore reports. In SG04-School 4 and SG05-School 5, staff ICT competence is offered as the main factor in successful implementation, while in SG03-School 3 it is ICT infrastructure. The difference between these two positions is that in SG04-School 4 and SG05-School 5, teachers are expected to develop Web-based teaching resources while in SG03-School 3 ICT is used primarily for communications. Therefore, when the technology fails in SG03-School 3, nothing can occur. Context, therefore, makes a difference. Where the demands on teachers are high, teacher competencies are critical. When the demands are mostly on the technology, it becomes the dominant factor. A further component of context emerges from the Finnish report, FI02-Oulu, which suggests that strong technical support for teachers reduces the need for strong teacher ICT skills, shifting the focus to infrastructure plus teacher ability to integrate ICT into teaching.

Staff ICT competencies and attitudes

77. One of the most important supports in most schools for fuller use of ICT is professional development, yet budgeted professional development time was lacking in many of the schools. In MX04-Quiróz, for example, professional development is neither provided within the school nor is time off provided to attend classes outside the school. In the past the state administrative authority has allowed parents to pay for substitutes so that teachers could spend time in the media room. This was not, however, part of a systematic professional development program nor was it guaranteed to continue much longer. In some cases such as FR01-Marie Curie, both teachers and students are required to go outside of the school for learning ICT skills; that is, no school ICT instruction is provided. In other places such as JP04-Gifu, no school seminars are offered for ICT but on-the-job training is carried out by teachers and support staff. In yet other places the staff development provided was considered by the teachers to be insufficient and too theoretical (e.g., PT04-Cabrieros). Similarly, teachers at KO01-Banghwa found an "inconsistency between the ICT training and its application in the classrooms."

78. A few programs offer staff development models for other countries to consider. At SG01-School 1, a core group of teachers, called ET Champions, were trained in depth on authoring tools and other Web-based technologies, along with pedagogical procedures with ICT. They then shared this knowledge with other teachers and also took responsibility for developing Web-based learning materials. In Sweden, a national programme, Tools for Learning, will reach almost half of all teachers in the country during the period 1999-2002. All will receive a computer as well as on-the-job training. A similar scheme implemented in the UK aims to develop teacher use of ICT for subject teaching and administration. Various programs exist there to support teachers' acquisition of computers. At HU03-Von Neumann teachers with special ICT training receive a computer for home use free from the school plus an ICT pay supplement. Alternatively, some countries have specified minimal levels of ICT training for teachers and left to local administrations and schools to carry out the instruction (e.g., The Netherlands). Most of the Danish schools reported successful staff development models realised through within building expertise. At DK01-Hjortespring, as an example, teachers can schedule assistance as needed from other teachers who have special ICT skills. Such an arrangement helps to create a secure environment for trying to use ICT in teaching and maximises the probability that assistance will be provided within the context where the need occurred.

79. To recapitulate the argument so far, both infrastructure and teacher competencies are required for successful implementation of ICT in a school; however, the balance of these two factors, above a critical level of infrastructure, depends upon the school context: how ICT is used and the amount of technical support available to teachers. But this is not the end of our clarifications. FI02-Oulu indicated two distinct types of teacher competencies: technical skills and curriculum integration skills. IT03-Rodari adds a third to the mix: general pedagogical ability, which probably relates to the ability to integrate ICT into a curriculum. We will, nevertheless, treat it as a separate ability. Finally, teacher attitudes toward teaching and toward ICT in general also figure into the implementation equation but exactly how is difficult to discern. JP01-Utase, among other schools, reported that some teachers were sceptical of the value of ICT for their subject areas and therefore didn't attempt to integrate it into their teaching. At KO01-Banghwa the teachers most negative toward ICT saw it as a tool to make their work easier while those most positive toward ICT saw it as support for higher level cognitive frameworks. The ways in which ICT is used is probably the most critical variable for determining its impact on student learning. We will, nevertheless, delay discussion of this issue until the concluding section.

80. Yet another distinction to examine is stage or phase of implementation. FI04-Lansimaki points out that in the initial stages of implementing ICT in a school, a reliable and user-friendly infrastructure is critical. As teachers become more technically competent, then their general pedagogical abilities and their ability to implement ICT into the curriculum become more important. A more advanced stage might also

be defined where a core set of ICT applications are institutionalised and teachers feel free to adapt ICT to their own style of teaching. For the present we will be content with a rough two-stage model, with early and later components. Further observation might reveal a more complex situation.

Components of ICT infrastructure

> "The reader must accept it as a fact that digital computers can be constructed, and indeed have been constructed, according to the principles we have described, and that they can in fact mimic the actions of a human computer very closely."
>
> A. M. Turing, Computer machinery and intelligence. Mind, 1950, 59:433-460.

Equipment

81. Since the new element in the reforms studied here is technology, it is important to understand how it is configured, used, and supported within the schools and what policies at a national or regional level lead to the realisation of its promise. What makes the task of understanding these features of technology so difficult is the wide range of technologies represented across the schools, the different stages of technology implementation and use reported, and the varied national, regional, and local contexts in which it is found. Even within countries these factors vary wildly. NO02-Røyse, for example, has a 2:1 student-to -computer ratio (SCR), a well-functioning wireless network, and almost every student has access to a computer at home. In NO01-Ringstabekk, in contrast, the SCR is 18:1 and almost all of the computers are in a room where teachers must reserve time. Students are not allowed to use the computers there unless a teacher is present.

82. A number of other schools report a 2:1 SCR or better, including US04-Pine City, FI02-Oulu, and SG02-School 2, but in Portugal the SCR for PT01-Resende is 26:1 and for PT04-Cabreiros, 25:1. Even where SCR's appear favourable, equipment may be obsolete. This is the case for IL02-Cramim, a technology-rich school where the equipment has not been updated in six years. In FI02-Oulu, half of the Internet-usable computers operate at speeds equal to or less than 200 mHz. UK01-Greenfield is developing plans for avoiding equipment obsolescence, as is NL02-Marke. But in most schools, equipment was under funded, often composed of mixtures of old and new machines that made maintenance and software updating difficult. Some schools had divided ICT tasks among different types of machines such that older, less powerful ones were dedicated to e-mail, print spooling, and other low throughput work and the more modern multimedia ones dedicated to the World Wide Web, page composition, graphics, and the like.

83. Many schools obtained all or a significant number of their computers through one-time funding: an infrastructure grant through the national or regional educational authority, corporate largess, etc. and have no regular replacement budget. DE03-Albani is a typical case, receiving equipment purchase funding as a World Exhibition School prior to 2000. Only a few schools reported satisfactory equipment replacement arrangements. One was NO02-Røyse, which has an agreement with the local authorities for equipment updating, whereby the municipality provides a sum equal to 8% of the school's total budget for maintenance and replacement of equipment and other components of infrastructure. Another was in Luxembourg, where the national educational authority replaces computer hardware and faulty equipment every three years. These cases were unusual, however. More typical was an air of resignation concerning equipment, as reflected in the report from DE05-Stein, which stated, "On the whole those interviewed described the computer equipment as not so good but, in comparison to other schools, above average". With limited resources, some schools have given their ICT skills courses first priority in access to computers, often leaving other teachers with little or no access (e.g., NL03-Jacobus). In a number of schools, including MX02-Anaya, equipment purchases were supported by parent contributions.

84. Several schools were using wireless networks and a few more were planning to convert to a wireless system. All networks except three were composed of multimedia computers; the three exceptions used what are called thin-client machines, which are equivalent to time-sharing terminals, with no hard disks or removable storage capacity (but often with connections for some peripheral equipment). Not even the most common applications such as word processors are stored locally. One site, US-04-Pine City, managed to provide 16 computers to each classroom through the adoption of thin client technology. The costs of these terminals was roughly one-third that of desktop computers. Besides computer equipment, schools reported a range of support equipment, including projection systems, satellite TV, digital and digital video cameras, scanners, and printers

Internet connections

85. For many sites, Internet connections were a sine qua non of their ICT plans. For others, such connections were considered essential but the actual percentage of machines connected to the Internet tended to vary by grade level. In Portugal, for example, about 89% of all schools above grade 3 (cycle 1) have Internet connections compared to 10% of those for grades 1-3. For schools such as NL01-De Verrekijker, NL04-Oost, NO02-Røyse, SG02-School 2, US04-Pine City, and IL02-Cramim, connections to the outside world, whether for community involvement, anytime/anywhere learning, parent access, or any other reason, were a basic necessity. In a few schools (e.g., FI04-Lansimaki) emphasis was placed on connecting the library to the Internet so that it could operate as an information centre. Schools varied in the percentage or number of machines connected to the Internet from MX04-Quiroz with only a single machine connected, to 40 sites where 100% of the machines in the school were connected. The latter group includes schools from more than half of the countries reporting (e.g., AT01-Steinbau, GR02-School B, IL04-Maale Shaharut, JP03-Fuchinobe, US01-Walnut Grove). These figures can be misleading, however, because bandwidth, firewall software, and other characteristics of the physical connections and communications software can limit the utility of Internet connections. So far we have no standard throughput measure for Internet connectivity comparable to the benchmark programs that are employed for measuring CPU speed and memory access.

Technical support

86. Even more limiting for ICT use were problems reported with technical support. Few schools described fully satisfactory schemes that brought industry standard responses to equipment or software problems. The city of Vienna, as an example, has a city-wide hardware repair scheme where, according to the AT01-Vienna report, responses to calls require up to two days and the actual repairs average almost 14 days. LU02- Biever states that "Technical problems remain a serious deterrent" to ICT use. Denmark also reported problems across most of its sites with technical assistance. One site, DK01-Hjortespring, reported slow response times for assistance and almost one-third of its 225 computers out of order regularly due to wanton destruction, general wear, and other causes. Where service is more acceptable, it is often at the personal expense of a teacher or school technical specialist who takes an "eight minute lunch and no breaks" (SE01-School 1). In a few schools (e.g., KO01-Banghwa, NL01-De Verrekijker, NL02-Marke) parents provided some of the technical support, either through installation of networks, maintenance of Web sites, or by assisting teachers with technical problems.

87. Technical support plans showed little consistency, especially in relation to satisfaction. Expecting teachers to squeeze repairs and technical support to others into their normal workload or giving small reductions in teaching hours, as is done at FI01-Aurora (1 hour per week) and DE05-Freiherr (four hours per week), does not appear to be a workable solution. More satisfactory is the plan at US02-Harland, where two full- time technical specialists have been hired to support 56 teachers plus the ICT

infrastructure, or at MX01-ESANS where a four-person team is in charge of the media area and equipment maintenance. At DK03-Kerby, technical assistance is provided through a combination of the school's own ICT co-ordinator and an unusually effective municipal data department. The US corporate standard of a full-time technical support person for every 50 computers is beyond the fondest dreams of most school administrators; nevertheless, unless schools have some reasonable level of regular support, it will be unreasonable to demand that teachers base their lessons upon ICT.

Student ICT competencies

88. Nine reports mentioned students as being important for successful implementation, but no report placed them alone as a primary factor. Instead, students were assigned a wide range of potential or real supporting roles. In FI03-Kupittaa they helped in the early phase to "get things going", as they did in SG02-School 2 where the strategy for introducing ICT was to focus first on student use and only later on teacher use. In IL01-Ohel Shem, where students were used as Web masters, their skills were considered important along with teacher skills and infrastructure. In NO02-Royse and US06-Joshua, students acted as peer tutors, thus helping teachers, to some degree, with technical issues that they might not have the time or ability to handle on their own. In MX01-ESANS students were often called on by teachers for technical assistance and in DK02-Korinth they were trained to upgrade and maintain equipment, as they were in DE01-Bonn-Beuel, DE04-Jules Verne, and DE05-Freiherr.

89. SE01-School 1 offers an interesting conjecture about such cases, based on the notion of co-opting students through their technical skills. "…motivation and status of students are raised in the pedagogical discourse. Here teachers probably pretend that students are successful when the meanings of school tasks are negotiated…and in the end many students seem to accept school better than before." The authors conjecture that teachers, as mature scholars, elevate in importance whatever technical abilities the students exhibit to bring the students into compliance with the schooling process. It is important, especially with the current rush of enthusiasm in many countries over ICT and constructivist teaching methods, to consider such social dynamics and their implications for schooling.

90. These reports can be interpreted to suggest that student involvement is a minor but potentially useful component of successful implementation, but it needs also to be seen in terms of the actual relationships that can occur. That is, rather than sharing wholeheartedly the satisfaction that other reports give when teachers and students become apparent equals in the ICT classroom, we suggest that attention be given to the stability of such relationships, to the locus of control, and to the differing perceptions of the relationship across students and teachers.

Summary

91. Both infrastructure and teacher competencies are required for successful implementation of ICT in a school. The balance of these two factors, above a critical level of infrastructure, depends upon the school context: how ICT is used and the amount of technical support available to teachers. In addition, during the initial stages of implementing ICT in a school, a reliable and user-friendly infrastructure is critical. As teachers become more technically competent, then their general pedagogical abilities and their ability to integrate ICT into the curriculum become more important. Teachers need time and support, however, to experiment with how ICT can be integrated into their teaching. The most successful staff development programs teach both ICT skills and related pedagogical skills, including how to integrate ICT in teaching. Student technical assistance is a minor but potentially useful component of successful implementation.

92. Co-ordinated planning across schools, regions, or at a national level was often involved when coherent plans existed for infrastructure, content, and professional development. Most of the schools reporting advanced applications of ICT were involved in larger national demonstration programs or other consortia that shared development and expertise: the Navigator Schools Program in Victoria, Australia, the Odysseia and YDEES Projects in Greece, the Nónio XXI Century Programme in Portugal, Sector Net in Denmark, Red Escolar and Project SEC21 in Mexico, various European Union co-operative projects (e.g., Comenius, Computer Supported Co-operative Learning), the Vienna Education Server, and the KIRPP project, sponsored by the regional government in Cologne, Germany. Although there may be some gain from teachers and administrators inventing and implementing their own approach to ICT, the time and expertise required to do this successfully is usually beyond the capacity of any single school.

Equity

> "Thin, fragile lightning bolts were flashing back and forth in the clouds when Dr. Fine repeated once more that what had turned his son against him had been a book. His son had read a book one day and thought his whole world had changed."
>
> Orhan Pamuk, The New Life. Trans. from the Turkish by Güneli Gün. New York: Farrar, Straus and Giroux, 1997, p. 129.

Social and economic performance gaps

93. Since educational innovations rarely act the same for all students in a classroom or school, it is reasonable to assume that extensive use of ICT in learning might favour some groups, defined by gender, academic aptitude, parent's SES, or some other factor, and be neutral or perhaps even negative for others. Through the various hypotheses and other issues defined in the Workbook, probes were made for the impact of ICT use on several sub-populations. The first issue concerns the gap in academic performance between students from different social or economic strata. Earlier studies (Hativa, 1988; Hativa & Becker, 1994) had shown that with CAI as the primary classroom instruction for middle school mathematics, the gap between high and low aptitude mathematics students widened considerably. Since aptitude for most academic subjects correlates highly with home conditions, and especially socio-economic status, we were concerned, therefore, that such a phenomenon might occur with other applications of ICT in the classroom.

94. The most general summary of the responses from the 94 reports we can give is that ICT in the classroom does not appear to be a cause of a widening performance gap based on social or economic factors. The majority of the reports found either no differences due to ICT or some cause to believe that the weaker and low SES students were helped more, due to increased access to educational resources and increased motivation for learning. Few reports offered any data, however, to substantiate a reduction in performance differences.

95. Concerns were expressed, nevertheless, for gaps in ICT skills created by differential access in the home to ICT. KO01-Banghwa reported that higher income students had better Internet access at home and tended to use the computers there more for information access and learning than low income students, who favoured on-line games and Internet chatting. There were also a few reports that the "better, more skilful, and advantaged" always learned more (FR01-Marie Curie, SE01-School 1) but these were counterbalanced by the observation that the school had control over the variables that made a difference for learning with ICT. NO03-Bokn pointed out that ICT gave the low ability students an opportunity to experience success and IL03-Neot David reported increases in low SES students of self-esteem and motivation from ICT involvement. Several other reports also described gains from ICT use for low ability students, including GR02-School B, IT01-Einstein, and SG02-School 2. Some reports highlighted gains in motivation,

presumably from low performing students (e.g., IE06-St. Luke, PT04-Cabreiros, UK02-Highgrove, UK03-Littlejohn), or gains in responsibility for their own learning (e.g., NL03-Jacobus, NL04-Oost). Two reports, LU01-Athenee and LU02-Biever, claimed that all students could benefit from ICT in one way or another, but the gap between strong and weak students would be likely to remain the same or even to widen.

96. Equally encouraging to the limited report of increases in performance gaps were the strategies adopted to ensure that students who did not have ICT access at home would receive sufficient ICT time at school. At KO01-Banghwa, students had access to an after school ICT laboratory. Parents of JP04-Gifu students are offered seminars once each month on ICT skills. In Canada, CA06-Lake View acts as a community Internet service provider and also provides technical support for the community as well as its feeder schools. At IT04-Tosi and UK03-Littlejohn, as in several other places, laptop computers are available for students to use at home. (The other two UK sites also provide considerable out-of-school support for computing.) At SG02-School 2, where first-year students are required to purchase laptop computers, financial assistance is available for those who need it. In Denmark, the Pioneer II Project is experimenting with the academic impact of home computers and provides them for all students in participating classes (DK03-Kerby). At NL04-Oost, students who do not have computers at home (some for religious reasons) can use the computers in the Information Centre at the school. This is but a sampling of the efforts made at many school sites to ensure that students without access to ICT at home will not be at a disadvantage in learning ICT skills or in using ICT for school work.

97. We cannot, from the data reported, discern how specific applications of ICT in the classroom impact high and low ability students. We can conjecture, nevertheless, from the earlier studies cited above, that the more students are left on their own for learning (as with CAI or unguided Web searching), the wider will be the performance gap between those with strong motivation and metacognitive skills and those with weaker allotments of these abilities. Viewed from the opposite perspective, the more ICT can support weaker students through structuring their time and study methods, and the more that ICT can offer on-going access to consistent learning materials, the more they will be helped in learning.

Gender differences

98. Analyses of ICT for gender-specific appeal have found a large bias in favour of boys/males (AAUW, 2000; Ordidge, 1997). Besides the bias in gender-specific appeal of computers and computer software, as elaborated in detail by AAUW (2000), Schofield (1995, 60) observed in a large urban high school in the US that girls "related to the computer as a tool to accomplish a specific task" while boys "appeared to be attracted to computers by the enjoyment and sense of mastery and accomplishment they got from exploring them." A large number of countries reported differences between how boys and girls approached ICT yet in no report were these differences presented as an important or pressing issue. In general, boys were found to be more interested in ICT, more willing to explore it, and more willing to devote time to using it. Girls were reported to be more inhibited in relation to ICT use. DE02-Bavaria described this latter difference as, "The boys first press all the keys, the girls first ask what could happen *if* they press a key."

99. A number of reports described other differential use patterns for girls and boys and one report, DK02-Korinth, reported a strong bias for boys in computer ownership at a boarding school. While 22 of 26 boys had computers in their rooms, only 1 of 23 girls did. AT03-Hall and KO02-Kyungin found that girls used chat rooms, e-mail, created 'nice' Web pages, and searched for information about movie stars while boys played more computer games and looked on the Web for sites concerned with sex or games. In NL04-Oost, girls were described as doing better in electronic learning environments because they were more structured and serious and worked better independently. Boys, on the other hand, were more driven by a

desire to be popular and made more noise. DE01-Bonn-Beuel also found that girls worked with ICT more purposefully, while LU01-Athenee found that in ICT use, boys are more attracted to scientific work, girls more to creative activities. However these differences might have developed, GR04-School D, NL01-De Verrekijker, and NL02-Marke reported that no differences were found for learning with ICT.

100. All of these differences appear to be general sex differences for the ages involved, with some variation by country according to the roles the different sexes play and how children are socialised to adult behaviour patterns (Rice & Dolgin, 2002). Judging from the progress made in a number of countries in creating more positive attitudes toward girls' abilities in and attitudes toward mathematics and science learning, any sex differences toward ICT that are unproductive for schooling and learning can probably also be changed (Chipman, Bush, & Wilson, 1985; Clewell, Anderson, & Thorpe, 1992; ETAN, 2000).

Other gaps

101. A more obvious positive impact was found for handicapped students, who were able to make friends with other students, including non-handicapped ones, through e-mail and chat rooms (AT03-Hall) or found it easier to express themselves (DE01-Bonn-Beuel). Similar advantages were also reported by DK03-Kerby for autistic children who attended special classes within the school. Learning for these children was facilitated by the computer's capabilities for visualisation as, for example, in making abstract concepts concrete. On the other hand, DK01-Hjortespring found that students with "massive learning disabilities still need remedial teaching with more direct contact."

Summary

102. ICT in the classroom does not appear to be a cause of a widening performance gap based on social or economic factors. The majority of the reports found either no differences due to ICT or some cause to believe that the weaker and low SES students were helped more, due to increased access to educational resources and increased motivation for learning. Although gender differences were reported, both in attitudes toward computing and in its use, they were not presented as barriers to the application of ICT to academic matters. Although few schools currently collect data that allow them to monitor gender, income, or ability differences, all are highly attuned to the potential inequalities that ICT might cause and have already or are working toward policies that minimise differential access within schools.

103. Some schools have adopted policies to reduce inequalities due to differences in the availability of ICT in the home. Some sites report support programs for home computing and some large programs exist for encouraging low income parents to obtain and use ICT in support of their children's learning (e.g., Rockman,1999). Such programs require financial support for equipment, maintenance, and Internet access; appropriate software for school-related work; and professional development and assistance for ICT use, including a hotline or equivalent to ensure timely assistance.

Academic quality

> "Have we not found copper by varnishing iron with laminar malachite? Indeed. Likewise we simulate gold by obducting silver with white of egg."
>
> Evan S. Connell, The Alchymist's Journal. New York: Penguin Books, 1991, pp. 68f.

104. In a hierarchical system of schooling, with a national or regional administration overseeing schools, which have lead administrators and then teachers who reign over classrooms, instructional

materials are reviewed at various levels before being allowed into student hands. Even library materials can be tightly controlled in such a system and academic quality is a function of the levels of aspiration, diligence, and competencies of the staff and administration. Once the boundaries of such a closed system are penetrated by computers and electronic access to the Internet, however, academic quality is at risk. Materials on the World Wide Web are more difficult to monitor, whether they are readings, instructional units, photographs, video clips, or any other form of information or entertainment. WWW sites face limited censorship in most countries, allowing anyone to place almost anything he or she chooses for public access. No policeman, editor, or school textbook adoption committee controls what is available for students to download. Pornography, hate literature, inchoate ramblings, and inaccurate descriptions are locatable through the same mechanisms as high literature, carefully edited encyclopaedia entries, and government statistics, and each travels at the same speed to a student's terminal.

105. A second quality issue relates to the pedagogy employed in educational sites on the WWW. According to a recent study of 500 educational sites, only 28.2% included inquiry-based activities and only 5% included problem solving or decision making (Mioduser & Nachmias, in press). In contrast, 42% of the sites featured rote learning and over 52% mainly involved information retrieval. The authors also found that critical pedagogical features for creating learning communities were missing from most sites. Similar findings were reported , also, in a recent OECD publication (OECD, 2001).

106. But inaccurate, biased, pornographic, or pedagogically vapid materials on the WWW are not the only threats to academic quality in schooling. Locating suitable materials for different age levels and areas of interest on the WWW is complex and time consuming. Indexing on the Web is in its infancy and students without good reading and skimming abilities and good search strategies can waste vast amounts of time trying to locate needed materials. Then, ease of copying through cut and paste operations in word processors and page composition programs presents a temptation to students to avoid restating ideas in their own words. Alternatively, teachers could focus too much on the visual appearance of student work, emphasising graphic arts over content, or could be satisfied with quantity of material retrieved rather than the quality of what was presented. Finally, time in the classroom devoted to ICT instruction usually implies time taken away from other types of instruction.

107. The obverse to this litany of fatal attractions is that through access to the WWW, students can encounter more timely, up to date materials than in textbooks, and at the same time can have access to a far greater variety of materials than are found in any school library. Expeditions, experiments, racing tours, and archaeological digs can be followed in real time, opposing perspectives on current events compared, and massive archives searched. Such resources in the hands of an experienced teacher might improve the quality of instruction.

Case study responses

108. The responses from the reports substantiated that quality issues emerged with ICT use but the reports also indicated that schools have found ways to cope with them and that, in general, the quality of instruction was not reduced through ICT applications such as searching for information on the Web. In the two Australian schools, "Staff members critically evaluate technical resources as they would other resources" (AU00-Summary). At IL03-Neot David, students are under "strict supervision" while on the Web. At NL01-De Verrekijker, students have access to only the Web sites that are available on the national educational network, Kennisnet. In FI01-Aurora and FI02-Oulu, as in several other schools, teachers are not dependent upon electronic learning materials. ICT is primarily a tool for their students. A similar situation existed at DK03-Kerby, which reported that "To some extent educational programmes have been given a low priority, as they are considered too expensive and of varying quality." In general, most schools report some restrictions on student access to the Web but at IE03-Peadar & Pol a more severe solution was

adopted. “Teachers have chosen not to integrate the Internet into their lessons as they fear it will have a negative effect on academic standards.” Concern that children would be exposed to pornographic materials was a further cause of WWW access restrictions at IE03-Peadar & Pol, as it was at the other Irish schools.

109. Several reports claim that standards were higher due to ICT access (e.g., FI03-Kupittaa, IL01-Ohel Shem, IL02-Cramim, IT02-Lepido) but one study, SE01-School 1, reported lower standards, and another report, DE00-Summary, cautioned that teaching ICT skills in content-area lessons took time from regular subject matter and therefore resulted in less content covered. This report also pointed out that “Easier access to information does not necessarily mean that the students keep it or process it”. SE01-School 1 also voiced a concern that the quality of learning was reduced due to excessive time seeking information on the Web rather than analysing it. A further issue was raised by KO02-Kyungin in suggesting that weaker students could become frustrated in trying to find information on the Web. Whether such frustration is greater for the Web than for textbook, magazine, or library searching is difficult to determine. Nevertheless, the possibility does exist that the quality of instruction could be lower for weaker students if it included open Web search activities. HU04-Almási suggested that novice and less qualified teachers were harmed the most by low quality materials on the Web. These teachers are usually the ones most dependent upon textbooks and other instructional materials and have the least ability to adapt materials to meet specific educational objectives. At least one report (KO02-Kyungin) described teachers who were overly dependent on ready made Web materials.

Summary

110. Schools are aware of the potential threat to academic quality created by ICT use, particularly through student searching on the WWW, and have adopted a variety of solutions for dealing with this problem. Besides the risk of children encountering undesirable and potentially harmful materials on the WWW and wasting vast amounts of time in unsystematic searches, Web based educational sites have been found to be rather bland, with rote learning far outweighing inquiry as the main pedagogical approach. A similar issue exists for teachers, especially less prepared ones who typically are dependent upon textbooks and other instructional materials and have the least ability to evaluate materials and to adapt them to meet specific educational objectives Whether students are learning any more now than they were 30 years ago about reading critically, distinguishing fact from propaganda, representing information, and detecting inconsistencies, ambiguity, and contradiction remains to be determined. Without well structured instruction for these, there is little basis for assuming they are being acquired. An information revolution based only on potential access to an exponentially expanding, unedited and unorganised archive is a rather limited revolution from an educational perspective.

LOOKING BACKWARDS, LOOKING FORWARD

> "Well, look at these drawings. Instead of those digging devices you see sticking out of the front end of our experimental model, the new one will have four electrodes spaced around the nose and a long guide vane sticking right out of the center."
>
> Victor Appleton II, Tom Swift and His Atomic Earth Blaster. New York: Grosset & Dunlap, 1954, p. 67.

111. In the opening of this report we spoke briefly of schools as learning organisations and went no further than to present this concept as desirable for the improvement of schooling. A few cases were found where either continuous progress models were in place (e.g., AU01-Bendigo, AU02-Glen Waverley, IE02-St. Sheila) or where components of a learning organisation were evident, such as DK03-Kerby, where ICT was used extensively by teachers to diffuse knowledge, both among themselves and to students and parents, thus creating a community of learners. DK04-Rugkobbel defined itself as a self-learning school that "consciously reflects on its own behaviour." As part of its improvement process it made a transition from an "I-culture" to a "we-culture." These cases reflect Fullan's (2001, p. 239) view that "Learning on the job is the sine qua non of improvement." ICT offers to schools a convenient means for continual professional development through collaboration, capture and diffusion of tacit knowledge, and data recording, analysis, and display. Many schools in this study have implemented intranets that support these ends; at present, however, only a few report professional development outcomes from such applications.

The impermanence of innovations

112. Intranets, Internets, and other applications of ICT are powerful tools for school problem solving; does this guarantee that the infrastructures reported in the 94 case study reports will still exist in 3-5 years? One of the major frustrations of modern schooling is the impermanence of innovations. What is here today may be here tomorrow but the likelihood of this occurring seems to depend on how compatible any new method is with what teachers traditionally do and believe, upon the context in which the change has occurred, and on the support system for the teachers. Rogers (1995) defines two basic reasons for the discontinuance of innovations: replacement with a more rewarding or effective innovation, and disenchantment because of a failure of an innovation to yield expected results. The literature on school change offers some interesting anecdotes, a plethora of case studies, but few trustworthy explanations for why innovations so often disappear with the speed of subatomic particles (e.g., Berman & McLaughlin, 1974; Fullan, 1999; Malouf & Schiller, 1995; McLaughlin, 1989).

113. Computer designers and software developers, along with some educators, have been promising a technology-based revolution in teaching for at least 40 years but until the World Wide Web began growing exponentially, schools exhibited limited enthusiasm for any use of computers outside of word processing, spread sheets, programming, and graphing and drawing. Even with pockets of support over the past two

decades for Logo, Pascal, BASIC, intelligent tutors, and computer games with an ostensible learning veneer, student-computer ratios until recently in most countries remained closer to 100:1 than to 10:1, thus blocking most attempts at integrating ICT into teaching. The exceptions were a small number of CAI systems, such as PLATO and TICCIT, that basked briefly in the sun prior to the microcomputer age and then rapidly disappeared from the classrooms (Venezky & Osin, 1991).

114. The World Wide Web, coupled with graphic interfaces and multimedia capabilities, has created a new potential, a new reality, and a new enthusiasm. But will it continue to spread within and across schools and will it survive the next national election, the next downturn in the economy, the next fad in instruction or in accountability? In most schools ICT has not become routinised; even in the most successful cases reported here, pockets of teachers remain who have yet to accept a need for integrating ICT into their teaching or to be prepared to do this. Among those who have begun these tasks, further professional development is often needed. In addition, many infrastructures are inadequate for the applications desired, and budgets for expansion are not currently available

115. How, then, will countries, regions, municipalities, and school districts maintain their current levels of ICT use and how will they complete the implementations under way? For many administrative units, in-depth reviews are needed of the current status of their ICT implementations, including their goals and the budgets, professional development, and other resources required to reach these goals. Then, plans need be developed for hiring, in-service staff-development, equipment purchase and maintenance, and the like. Schools that have regular cycles of goal setting, indicator monitoring, and review already are engaged in such planning with their higher administrative units. Central administrations can help through the adoption of policies and procedures that encourage or require ICT infrastructures and competencies. For example, in a few countries (e.g., Hungary), schools are already required to submit data on-line to the Ministry of Education.

Can ICT reach all schools?

116. The next question to ask about the future of ICT in schooling concerns the mechanisms for reaching all schools in a country. This is the problem of scaling up from a small set of schools to an entire region or state or country, a problem often mistakenly treated as an issue of how to transfer what works at one school to other schools. We see the problem quite differently and suggest that the term "transfer" is misleading in this context. Many of the schools reported here participated in demonstration projects where extra resources and supports were made available. As mentioned earlier, some were (and continue to be) involved with university research projects that provided professional development, coaching, and teaching materials, thus making them impractical models for national or regional implementation. But more importantly, years of research on school change show that the implementation plans that work best for any school are a function of the attitudes and abilities of the staff, the quality of leadership, the role played by parents, the community and national context, and the resources available (Elmore, 2000; Fullan, 1999). Most of the plans reported here developed over many years and were adjusted continually to staff, student, administrative, and community changes.

117. Although several schools were funded to provide information to other schools on their ICT activities as a step toward the facilitation of transfer, we conclude from the entire set of case studies that transfer of one school's plans to another is not a productive perspective to take on spreading ICT across a wider number of sites. Unlike the importation or transfer of a housing blueprint from one location to another, a major school improvement requires much more than just a level foundation to be built. Instead, scaling up should be viewed as creating the conditions at other sites that would encourage the development or adaptation of successful ICT models. Successful implementation of ICT, however, is not simply a technical issue. It requires a vision about education and about the specific educational goals that ICT is to

support. An ICT plan by itself is incomplete. As was stated in the first part of the Results section, policy makers should ask school administrators first for a strategic schooling plan and then for an ICT plan for supporting their school's educational goals.

The role of ICT in the future

> These things are in the future;
> present tasks claim our care:
> the ordering of the future rests
> where it should rest.
>
> *Final chorus.* Sophocles, Antigone, p. 233.

118. Assuming systematic school planning, what ICT applications should we expect to see the coming years in schools? We speculate, based upon the most mature schools, that most applications of ICT beyond open tools will be managed through a virtual network where students have their own password-protected workspaces, keep portfolios of their work, submit homework and receive teacher feedback, and access course materials and general resources. Such systems will allow anywhere/anytime learning, and facilitate collaborative projects and communications with teachers, tutors, and peers. The interfaces for such virtual environments will probably change for different age or grade levels, building toward a style that is compatible with life-long learning sites by the end of secondary school. A few systems now in use such as Learning Space in The Netherlands (NL04-Oost) are first steps toward this level of sophistication.

119. Many teachers will contribute to the content of these sites, either through their own lesson and resource designs or through selection of materials developed by others. By the middle of the elementary grades, students should acquire reasonable typing skills and use open tools for preparing reports, storing and analysing quantitative data, and presenting conclusions. By entry to the secondary level, students should prepare simple Web pages, use e-mail for communications, and do guided searches on the Web. By the conclusion of secondary school, students should master the use of open tools, prepare complex Web pages, search intelligently for information, and access a wide variety of software learning programs and participate in virtual courses.

Professional development

120. To achieve the vision just presented will require teachers and administrators who are ICT and pedagogically savvy, yet just maintaining current (and often inadequate) levels of staff ICT competence is problematic for many schools. ICT use among teachers is not an irreversible process; leadership changes, staff turnover, and loss of technical support can negatively affect the diffusion process. At CA12-Crocodile Valley, staff turnover led to a drop from 75% of the teachers using ICT regularly to under 50%. A teacher at DE03-Albani reports that "If [the technical specialist] left, that would be a nightmare. Many things would come to an end." Staff turnover is a barrier to sustainability at a number of sites, including GR02-School B, where both the technical co-ordinator and the principal will be leaving over the next two years, and at HU02-Karinthy where 10% of the staff leaves each year. Yet many schools also report that ICT has become a way of life for their teachers and is unlikely to disappear. IL03-Neot David is typical of many schools in recounting how their teachers did not enter the world of ICT voluntarily but now that they are there they find ICT to be the normal way of life, providing a better professional future. Mastery of ICT skills and of teaching with ICT reduced their anxiety levels and made them more open to change and to innovation. Through pre-service and in-service education and through personal effort, teachers should become model citizens of the digital world.

121. Although professional development in ICT for teachers is being stressed world-wide, equal emphasis needs to be placed on administrative training for knowledge management, teamwork, community relations, and creating a culture of innovation and of mistakes--what in Germany is called "Fehlerkultur." Successful implementation of ICT in the classroom requires building-wide support that only a principal or headmaster can create. Instructional innovation cannot occur in an environment that teachers perceive as punitive and unforgiving. Learning to use ICT for teaching, like learning to ski, rarely occurs without mistakes. Administrators who understand the culture of innovation can create environments that encourage experimentation.

Epilogue

122. How, then, to sum up? What flows from the spigot when we distil all 94 reports, five hypotheses and the accompanying summaries and recommendations? What are the lessons learned? What must be done to enjoy the full promise of ICT? One conclusion that emerges strongly is that technology is not a replacement for education nor is it a revolutionary force that requires traditional education to strip itself naked and be totally recostumed. What we have learned over the last 100+ years about effective schooling, teacher practices, cognitive development, curriculum, and the like has not been rendered obsolete by the multi-gigabyte disk, the 1,000 megaherz processor, and the latest operating system. The filtering of information through the sense organs, the synaptic firings of the cerebral cortex, and the learning properties of the brain have not been changed by ICT. In fact, the attempt to integrate ICT into teaching has made the importance of a knowledge base on learning even greater.

123. Good education does not need to change to accommodate the particularities and power of technology. Instead, technology needs to change to accommodate to good educational practices. Courseware needs to take into account what is difficult for teachers to teach rather than attempting to do everything that a teacher can do. Good teachers need resources that they can configure for different learning needs, not total packages that try to teach full courses. Teachers also need information for decision making, delivered when it is needed in a form that is manageable under classroom conditions. It is remarkable that engineers are capable of studying the perceptual, emotional, and cognitive demands on a jet fighter pilot under combat conditions and have adapted information systems accordingly but yet are incapable or unwilling of analysing the flow of competing demands in the classroom and rendering the same service to teachers. A classroom is a booming, buzzing confusion, with simultaneous voices, activities, and objectives. As on the battlefield and in the factory, technology could be adapted to control the flow of information, inform decisions, and track activities and outcomes. Such needs are primarily for new software that is designed for classrooms and teaching laboratories rather than for banks, secretarial stations, and accounting offices.

124. Beyond this general need, there are stage directions for the actors at all levels of national educational systems. At the top level, ICT needs to assume its rightful place in national or regional budgets, curriculum, and examinations. If ICT skills are required for survival in the world of today and tomorrow, then they should be taught in the curriculum and tested at appropriate intervals. Teachers in many countries are currently receiving conflicting messages on ICT. National and local interests want ICT skills taught but at the same time nothing is changed in the national curriculum and in the national examinations to accommodate these abilities. One exception is Luxembourg, where the progressive introduction of ICT use in learning and teaching will be explicitly mentioned in the mandatory curriculum and where ICT skills in mathematics will be part of the final examination for the school-leaving certificate for secondary schools within five years.

125. In the colleges, universities, and normal schools, pre-service education needs to adjust to the digital world. Graduates of the teacher education programs should not only be comfortable with ICT applications but also should understand the importance of innovation and of change. Today's technology

probably will not be tomorrow's technology. Knowing how to use a specific search engine is not as important as understanding the problems in organising and retrieving information from systems like the World Wide Web. The European Computer Driver's Licence may represent ICT competency for today but for tomorrow more advanced understanding will be required.

126. At the school level several changes are imminent. Intranets and Internets allow schools to create their own communities, drawing together people from around the world to enhance the learning, cultural identity, and occupational opportunities of their students. For schools to draw benefits from this community building ability, they need more flexibility in budgeting and in staffing. In Australia today, for example, some states allow schools to hire their own teachers. In many other countries (e.g., Italy) schools play a more limited role in their own staffing.

127. As stated several times in the Summary section, schools need to define how ICT is best used in instruction and provide teachers and classrooms with the equipment and technical support necessary to achieve these goals. If, for example, students are to work primarily in groups, with an emphasis on investigation of issues and presentation of results, then multiple display systems will be needed so that several groups can practice their presentations at the same time. If teachers are expected to create their own Web-based instructional materials, then software tools are needed to facilitate page composition, animation, graphing, and other functions. Besides including more effective teaching of ICT skills, the school curriculum should engage knowledge management, information literacy, and the reading skills needed for skimming and evaluating texts for relevance, accuracy, bias, and completeness. In-service staff development is also required, and judging from the reports received here, should focus on pedagogical issues, perhaps with group-based approaches and in class mentoring. Innovative instructional improvement approaches such as the lesson study plan (Stigler & Hiebert, 1999)might be helpful in developing ICT-based lessons.

128. As someone long ago quipped, "Prediction is difficult, especially of the future." What is not so difficult to predict is the continuing growth in the power of ICT and its potential for supporting innovative approaches to schooling. Whether we embark, like a Star Trek adventure, into new and uncharted realms of teaching and learning or circle again and again over the already explored terrain of traditional education is a function not of the power of ICT but of our creative imagination.

SUMMARY OF FINDINGS

129. As Pasteur noted long ago, "In the fields of observation, chance favours only the prepared mind." So does ICT favour the prepared organisation. No miracles derive from the mere presence of ICT in a school; it does not, except in unusual circumstances, act as a catalyst for wide scale improvements. Instead, ICT can be a powerful lever for change when new directions are carefully planned, staff and support systems prepared, and resources for implementation and maintenance provided. Unlike other levers available to schools, however, ICT has the power to facilitate vast changes in instruction, in home, community, and school relations, and in school management. It should not be viewed as a simple tool, to be considered only after changes are planned, but as a more powerful ally that can help schools aspire to and reach the highest goals of education. Furthermore, once reform with ICT is implemented, a climate for innovation may remain wherein ICT can act as a catalyst for further changes.

130. The adoption of ICT within a school generally followed a traditional pattern for diffusion of innovations. The exceptions were schools that were able to select their teaching staffs at least in part on the basis of ICT abilities or attitudes or schools where external forces were strong enough to override the normal diffusion pattern. Within any school, acquisition of ICT skills by the teaching staff may not lead to deployment of these skills for teaching. Degree of diffusion, including what is defined as completion of diffusion, depends upon the expected applications of ICT and therefore cannot be universally defined. However, sufficient professional development opportunities and support, compensated time off for training, and an adequate ICT infrastructure present the optimal conditions for advancing the adoption of ICT by a school staff. Diffusion can stall or retreat without appropriate leadership or without the supports just described.

131. Both infrastructure and teacher competencies are required for successful implementation of ICT in a school. The balance of these two factors, above a critical level of infrastructure, depends upon the school context: how ICT is used and the amount of technical support available to teachers. In addition, during the initial stages of implementing ICT in a school, a reliable and user-friendly infrastructure is critical. As teachers become more technically competent, then their general pedagogical abilities and their ability to integrate ICT into the curriculum become more important. Teachers need time and support, however, to experiment with how ICT can be integrated into their teaching. The most successful staff development programs teach both ICT skills and related pedagogical skills, including how to integrate ICT in teaching. Student technical assistance is a minor but potentially useful component of successful implementation.

132. Co-ordinated planning across schools, regions, or at a national level was often involved when coherent plans existed for infrastructure, content, and professional development. Most of the schools reporting advanced applications of ICT were involved in larger national demonstration programs or other consortia that shared development and expertise-the Navigator Schools program in Victoria, Australia, the Odysseia and YDEES Projects in Greece, the Nónio XXI Century Programme in Portugal, Sector Net in

Denmark, Red Escolar and Project SEC21 in Mexico, various European Union co-operative projects (e.g., Comenius, Computer Supported Co-operative Learning), the Vienna Education Server, and the KIRPP project, sponsored by the regional government in Cologne, Germany. Although there may be some gain from teachers and administrators inventing and implementing their own approach to ICT, the time and expertise required to do this successfully is usually beyond the capacity of any single school.

133. The ICT applications that transformed schooling the most involved advanced communications, bringing together different partners in the delivery of instruction, creating communities centred around the schools, and delivering materials and instruction on an anytime/anywhere basis. Few schools reported cutting edge applications of ICT to instruction such as intelligent tutors, expert diagnostic systems, or simulations. One reason for the absence of these latter applications is the lack of enough high power computers within a class or school to allow all students to have on-going access to ICT. A second is that few such applications are available to schools, especially in languages other than English. A further problem, which we can only speculate on here, is that the cutting edge tutoring systems, simulations, and the like were not designed adequately for teachers to use them as a resource in their teaching.

134. ICT in the classroom does not appear to be a cause of a widening performance gap based on social or economic factors. The majority of the reports found either no differences due to ICT or some cause to believe that the weaker and low SES students were helped more, due to increased access to educational resources and increased motivation for learning. Although gender differences were reported, both in attitudes toward computing and in its use, they were not presented as barriers to the application of ICT to academic matters. Few schools currently have data that allow them to monitor gender, income, or ability differences.

135. Countries are highly attuned to the potential inequalities that ICT might cause and have already or are working toward policies that minimise differential access within schools. In addition, some have adopted policies to reduce inequalities due to differences in the availability of ICT in the home. Some sites report support programs for home computing and some large programs exist for encouraging low income parents to obtain and use ICT in support of their children’s learning (e.g., Rockman,1999). Such programs require financial support for equipment, maintenance, and Internet access; appropriate software for school-related work; and professional development and assistance for ICT use, including a hotline or equivalent to ensure timely assistance.

136. Schools are aware of the potential threat to academic quality created by ICT use, particularly through student searching on the WWW, and have adopted a variety of solutions for dealing with this problem. Besides the risk of children encountering undesirable and potentially harmful materials on the WWW and wasting vast amounts of time in unsystematic searches, Web based educational sites have been found to be rather bland, with rote learning far outweighing inquiry as the main pedagogical approach. A similar issue exists for teachers, especially less prepared ones who typically are dependent upon textbooks and other instructional materials and have the least ability to evaluate materials and to adapt them quickly to meet specific educational objectives Whether students are learning any more now than they were 30 years ago about reading critically, distinguishing fact from propaganda, representing information, and detecting inconsistencies, ambiguity, and contradiction remains to be determined. Without well structured instruction for these, there is little basis for assuming they are being acquired. An information revolution based only on potential access to an exponentially expanding, unedited and unorganised archive is a rather limited revolution from an educational perspective.

POLICY OPTIONS

From the findings of this report we have identified policy implications or options for three different groups: national and regional educational administrations, schools, and pre-service teacher preparation institutions.

National/Regional educational administrations

- National educational goals, as communicated to the public and to the educational community, should stress the importance of ICT as a tool for assisting schools to become more effective and efficient rather than as a force majeure that will compel schools to change.

- National and regional educational administrations should encourage sharing of expertise and resources across schools that fall within the same administrative unit or that are allied by location or curriculum. Municipal or regional networks for accessing lesson plans, source materials, administrative software, discussion groups, collaborative learning opportunities, and the like; consortia for sharing maintenance costs; and joint staff development workshops and summer institutes are among the activities that educational authorities can sponsor for accelerating implementation of ICT within schools.

- Governments and other administrative bodies should facilitate the collection of school data for monitoring differential performance of sub-populations related to gender, income, and ability differences. In some countries, other sub-populations could be of interest; e.g., native born vs. immigrant. A set of indicators should be defined along with the techniques for monitoring them. This might involve the designation of analyses on data already collected or it may require specified software to store, summarise, and display results from new data. The regular collection of data on sub-populations would also allow schools to consider value-added approaches to accountability.

- National and regional efforts to monitor and report on the quality of educational software should be encouraged.

Schools

- ICT implementation at a school level should be viewed in the context of school improvement plans and not simply as a technical issue Problems that the school faces should be identified, strategies for overcoming these problems designed, and progress indicators designated. The highest returns on ICT in education appear to come when ICT is seen as part of a strategy for solving an important problem rather than as an end with itself.

- If a school wants to have ICT integrated into its instructional program and also to use it for communications among staff, parents, and community, then it must first provide an adequate infrastructure and support system, along with continuing staff development opportunities. The latter need to be practical and to focus on pedagogy rather than on ICT per se. The school needs also to provide incentives for staff compliance and monitor the adoption process. Without incentives and monitoring, the diffusion of ICT through the staff will generally be slow, requiring multiple years to reach the critical mass required for school wide, routine use.

- The planned uses of ICT within a school should be carefully defined and should drive staff development for ICT, incentives, and monitoring of adoption. Emphasis in school and teacher evaluations needs to be placed on the types and quality of ICT use according to such a plan and not on hours of ICT training received by the staff.

- Teacher contracts, as negotiated with labour unions and educational administrations, should ensure adequate professional development within normal working time for ICT and ICT integration into teaching.

- The desired ICT infrastructure for a school should be defined in terms of school pedagogical goals, translated to types of ICT usage desired rather than to physical terms such as student/computer ratio or number of classrooms connected to the Internet. To support this approach to planning, educators and technical experts, working together, need to determine the range of different infrastructure configurations required to enable different instructional plans.

- Like businesses and national and regional administrative offices, schools need full-time, resident technical assistants to maintain equipment and software and to support their staffs in utilising ICT.

- Schools, with assistance from municipalities and from higher educational administrations, should develop programs for assisting low income families in obtaining and using ICT for home support of schooling. Such programs might involve laptop computers that are loaned to students or families for home use, low interest loans, or grants. Where possible ICT training programs and assistance mechanisms (e.g., phone hot-line) should be included.

Teacher preparation programs

- Pre-service education of teachers should include lessons on evaluating electronic materials for pedagogical value as well as content.

The king’s a beggar, now the play is done;
All is well ended, if this suit be won,
That you express content; which we will pay,
With strife to please you, day exceeding day:
Ours be your patience then, and yours our parts;
Your gentle hands lend us, and take our hearts.

Epilogue to <u>All’s Well That Ends Well</u>.
William Shakespeare

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APPENDIX A

OECD/CERI ICT Programme

NOMINATION FORM FOR A SCHOOL SITE

Note: This form should be edited for conditions and terminology that may vary in your country or with the sites you will be choosing among. Keep in mind, however, that the data gathered through this form should inform categories 4-7 in the Organisation of Evidence chart at the end of the Workbook.

A. Name and address

Name and address of site:
Web site (if one exists):
Telephone/fax:
Name, title, phone, and e-mail address of lead site contact:

B. Basic site description

Type of site (age levels/grades, public/private, special populations or services):
Location of site (urban, inner-urban, suburban, small town, rural):
Socio-economic status of parents (describe indicator used):
Number of students plus notes on any imbalances in representation by gender or citizenship:
Percentage of students moving to another school before the end of the academic term:
Total site budget:
Percentage of budget (approximately) spent on ICT:
Sources of income:
Other significant resources received in the past two years (volunteers, corporate donations, etc.):

C. Staff

Name, title, phone, and e-mail address of lead administrator:
Administrative structure (departments, special educational needs arrangements, roles of staff):
Number of staff:
Percentage of staff who do not complete the full academic year:
Average number of hours spent teaching for teachers whose primary assignment is classroom teaching:

D. Academic schedule and performance

Academic schedule (start/end dates, weekly days/hours):
Organisation of instruction (timetable type, special educational needs provisions, etc.):
Formal assessment procedures (types of tests, dates given, purposes):
Student performance levels for mathematics and reading (or equivalent) at two representative student year groups:

E. Improvement/Innovation

Description of improvements or innovations (400-500 words--please attach, along with relevant documentation).
Main indicators of success of the improvements:
Role of information and communication technologies (ICT) in improvements (400-500 words—please attach).

F. ICT

Brief description of the main technologies (ICT) used at the site:
Total number of WWW-usable computers
Total number of other computers
Locations of computers (labs, classrooms, library, etc.)
Type of Internet connection
Are computers and the Internet accessible to students and teachers beyond class time?
Main uses of ICT in the curriculum:
Brief description of the ICT technical and pedagogical support provided to students, teachers, and administrators:
Main indicators of successful use of ICT:

APPENDIX B

OECD/CERI ICT PROGRAMME

ICT PRACTICES SURVEY FOR TEACHERS

Instructions
This survey requires about 15 minutes to complete. Please answer each question briefly but concisely, being totally objective. You need not add your name to the survey but may do so if you so choose. The research team and the OECD ICT Programme staff thank you for your time and your co-operation.

How comfortable are you with using a computer to do each of the following? (Choices are: very comfortable, comfortable, somewhat comfortable, not at all comfortable)

1. write a paper
2. search for information on the World Wide Web (WWW)
3. create and maintain web pages
4. use a data base
5. develop a data base
6. send and receive e-mail
7. write a program
8. draw a picture or diagram
9. present information (e.g., use PowerPoint or equivalent)

How important is each of the following computer-related skills for your teaching? (Choices are: very important, important, so-so, and not important at all)

10. write a paper with a word processor
11. search for information on the WWW
12. create Web pages
13. use a data base
14. develop a data base
15. send and receive e-mail
16. write a program
17. draw a picture or diagram with a graphing/drawing application
18. present information (e.g., use PowerPoint or equivalent)

During the past school year, how often did your students on average do the following for the work you assigned? (Choices are: several times each week, several times each month, a few times, never)

19. use the World Wide Web
20. create web pages
21. send or receive e-mail
22. use a word processing program
23. use a computer to play games
24. use a spreadsheet
25. use a graphics program
26. join in an on-line forum or chat room
27. use a presentation program (e.g., PowerPoint)
28. use an instructional program (including simulations)
29. other computer uses (specify)

30. How would you rate your ability to use a computer? (Choices are: good, fair, poor)

Answer questions 31-38 based on experiences or policies from the last school year.

31. Was student computer use ever evaluated for grading? (yes-no)

32. If you assigned World Wide Web searching, how much freedom did you allow students in locating sites to visit? (no restrictions, some restrictions, designated sites only)

33. Did you create or modify a Web site with any of the classes that you taught? (yes-no)

34. What portion of the computer use in your classes was directly related to the course content? (all, most, some, very little)

35. What portion of the computer use that you assigned was done by students individually? (all, most, some, very little)

36. If you have a computer at home, how often did you use it for preparing for teaching? (several times a week, several times a month, a few times, never, no computer)

37. Did you participate as a student or instructor in a virtual course through the Internet/World Wide Web? (yes-no)

38. Did you involve your students in collaborative learning over the Internet/World Wide Web with students from other classes? (yes-no)

39. Are you currently using technology to collaborate with other teachers (professional chat rooms, forums, or the like)? (yes-no)

40. How many e-mail messages do you send each week on average? (more than 12, 6-11, 1-5, none).

How many of the following have you ever done?

41. made changes to a computer's hardware

42. updated an application program (word processor, graphics program, etc.)

43. recovered a damaged file

44. created a web site

45. developed a data base

APPENDIX C

CASE STUDY SITES-DESCRIPTIVE DATA

NO.	Code	Grades	Type	No. Stud	No. Teach	Income Level	SCR	% Internet	Support	Computers
1	AT01	lower sec-	public	269	37	low	8	100	middle	massed
2	AT02	lower sec -	public	241	34	middle	7	100	low	massed
3	AT03	lower sec -	public	268	28	middle	10	100	low	distributed
4	AT04	lower sec -	public	229	26	middle	10	100	middle	massed
5	AT05	lower sec -	public	262	26	middle	6	100	low	massed
6	AU01	upper sec	public	1787	113	middle-high	4	90	high	distributed
7	AU02	intermed +	public	1830	125	high	4	100	high	distributed
8	CA01	sec	public	1050	68	middle-high	3	x	high	distributed
9	CA02	elem	public	437	21	middle-high	x	100	x	distributed
10	CA03	elem	public	300	x	low	5	83	x	distributed
11	CA04	x	public	x	x	x	x	x	x	distributed
12	CA06	compreh	voc	704	x	low-middle	2	92	x	distributed
13	CA11	x	virtual-voc	1000	x	middle	x	x	x	x
14	CA12	sec	public	1050	60	low	5	x	middle	distributed
15	DE01	sec+	public-comp	1351	125	low-middle-high	11	90	low	distributed
16	DE02	sec +	public	1082	91	high	27	75	low	massed
17	DE03	prim+	public	220	16	low-middle-high	16	99	high	massed
18	DE04	sec +	public-comp	870	70	middle	16	88	low	massed
19	DE05	sec +	public-comp	1200	105	low-middle	58	60	low	distributed
20	DK01	elem +	public	800	70	low-middle-high	4	31	middle	distributed
21	DK02	lower sec+	Continuing	55	9	low-middle-high	6	100	high	distributed
22	DK03	elem -	public	300	38	middle	4	41	high	distributed
23	DK04	elem +	public	450	37	middle	5	70	high	distributed
24	DK05	prim-sec +	private	1100	130	high	6	27	middle	distributed
25	FI01	elem	public	332	19	middle-high	20	50	low	diffused

26	FI02	sec -	comp	261	43	middle	2	80	high	massed
27	FI03	upper sec+	voc	356	31	middle	7	93%	low	mixed
28	FI04	lower sec +	public	381	34	low	8	100	high	mixed
29	FR01	upper sec +	voc	1350	120	low-middle	5	90	high	distributed
30	GR01	elem	private	632	56	high	11	50	low	massed
31	GR02	elem	public	185	15	x	18	100	high	massed
32	GR03	lower sec	public	294	33	low	30	100	low	massed
33	GR04	lower sec	public	330	25	middle	17	50	low	massed
34	GR05	lower sec	public	227	26	x	x	x	high	x
35	HU01	sec+	private	420	59	middle-high	3	75	high	massed
36	HU02	sec+	private-voc	720	62	low	5	69	x	massed
37	HU03	elem	private	485	41	low	27	75	x	massed
38	HU04	sec+	private-voc	700	51	middle	10	70	x	distributed
39	HU05	upper sec	public	625	69	middle-high	10	95	x	massed
40	HU06	sec+	state-voc	720	62	low-middle	6	76	middle	massed
41	IE01	elem	public	320	17	high	9	55	low	distributed
42	IE02	elem	public	292	14	middle-high	5	100	middle	massed
43	IE03	elem	public	81	3	low	3	3	low	distributed
44	IE04	sec +	public	1050	70	low-middle	21	100	middle	massed
45	IE05	sec +	private-rel	780	70	middle	15	100	middle	distributed
46	IE06	sec +	rel	455	37	low-middle	6	100	low	distributed
47	IL01	upper sec +	public	1250	120	middle-high	10	100	low	distributed
48	IL02	elem	public	1000	40	middle	7	100	high	mixed
49	IL03	intermed -	public-rel	623	50	low-middle	7	31	middle	massed
50	IL04	elem +	public	715	380	low-middle	8	100	high	massed
51	IL05	Lower sec	public	635	53	middle-high	6	100	middle	massed
52	IT01	sec	voc	800	120	low middle	7	75	low	massed
53	IT02	lower sec	public	332	31	middle	11	50	low	massed
54	IT03	elem +	public	248	27	high	8	100	high	distributed
55	IT04	sec +	voc	1384	114	low middle	9	100	high	distributed
56	JP01	lower sec	public	259	16	x	4	95	low	mixed
57	JP02	elem	public	421	26	x	x	x	high	distributed
58	JP03	elem	public	1003	39	x	14	100	high	mixed
59	JP04	lower sec	public	487	38	x	4	98	low	mixed
60	KO01	elem	public	x	x	low	x	100	x	distributed
61	KO02	elem	public	1353	36	middle-high	x	100	high	distributed
62	LU01	sec +	public	1350	167	middle-high	7	100	low	distributed
63	LU02	sec +	public-voc	1150	137	low-middle	11	100	low	mixed
64	MX01	lower sec	public	x	x	x	15	x	x	distributed
65	MX02	lower sec	public	500	40	x	5	100	x	massed
66	MX03	sec	public	300	x	x	6	95	x	distributed
67	MX04	elem	public	x	x	x	x	x	x	massed
68	NL01	middle	rel	320	15	middle	9	100	high	mixed
69	NL02	elem	rel	235	15	middle	3	100	high	mixed
70	NL03	lower sec	rel-comp	1100	70	mixed	12	100	high	massed
71	NL04	upper sec	agricultural	750	50	mixed	15	50	middle	massed
72	NO01	lower sec -	public	342	35	middle-high	18	x	low	massed
73	NO02	elem?	public	137	15	middle-high	2	100	high	mixed
74	NO03	elem?	public	104	12	high	8	x	high	distributed
75	PT01	sec +	public	845	112	low	26	100	low	distributed

76	PT02	sec	public	1150	98	low-middle	19	60	low	mixed
77	PT03	lower sec -	public	605	79	middle	5	20	low	distributed
78	PT04	lower sec -	public	602	53	low	25	100	low	massed
79	PT05	sec	voc	640	100	middle-high	6	100	low	distributed
80	SE01	elem +	public	6000	x	middle	8	90	x	massed
81	SG01	upper sec +	public	1500	149	middle	3	60	low	distributed
82	SG02	upper sec +	voc	14378	800	middle	10	100	high	distributed
83	SG03	lower sec	public	1415	70	high	5	50	low	mixed
84	SG04	lower sec	public	1458	69	middle	4	100	high	distributed
85	SG05	intermed +	public	2919	121	middle	16	35	low	distributed
86	UK01	sec +	public-comp	1850	100	x	3	75	x	distributed
87	UK02	sec +	public	1914	140	low-middle	5	60	x	distributed
88	UK03	intermed	public	234	8	low	3	60	x	distributed
89	US01	elem	public	768	40	low	5	100	low	distributed
90	US02	elem	public	817	56	high	1	100	x	distributed
91	US03	middle	public	1338	133	high	4	100	low	massed
92	US04	middle	public	800	36	low	2	100	x	distributed
93	US05	upper sec	comp	240	11	x	1	100	x	distributed
94	US06	lower sec	public	500	x	high	2	100	x	distributed