ICT in Innovative Schools: Case Studies of Change and Impacts[1]

1. Introduction: ICT and School Reform

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

Across OECD countries, far-reaching changes are occurring in schools. A variety of instructional reforms is 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, especially the traditionally marginalised. Other countries are depending more on improved staff development and revised curricula, emphasising learning to learn as well as interactive, collaborative skills. Life-long learning is also a major concern although policies and programmes aimed at this broad area are often not visible in schooling.

In parallel with educational reform 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-competent teachers. Building initially on the foundation of educational computing created in the 1980s, which centred on computer-assisted instruction, this movement took a dramatic step forward in the 1990s by stressing professional development for teachers to use technology and focusing on the 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 programmes and integrated learning systems that dominated ICT use in many countries in the previous decades.

A major research programme on ICT and the quality of schooling was undertaken by OECD's Centre for Educational Research and Innovation (CERI) in response to these developments. This section of the report presents and discusses the findings from 93 case studies of ICT and organisational change. These were done by the 22 participating countries with the fieldwork completed by 2001[2]. The primary goal of the case studies is to understand how ICT relates to educational innovation. They 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 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. The case study schools were identified in their own countries as innovative.

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[1] The main author and researcher coordinating this study was Richard Venezky, University of Delaware, United States. His longer report was subsequently edited by Aidan Mulkeen, National University of Ireland, Maynooth.

[2] The participating countries were: Australia, Austria, Canada, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Japan, Korea, Luxembourg, Mexico, the Netherlands, Norway, Portugal, Singapore, United Kingdom, and the United States. The names of the schools, unless referred to anonymously, are found in the text preceded by their county acronym. The original case studies can be found at http://www.oecd.org/document/55/0,3343,en_2649_34519_33932151_1_1_1_1,00.html

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While they are undoubtedly not typical, they are not so different from ordinary schools that the lessons arising from their experiences do not apply to others. They offer a preview of the issues to emerge as ICT is adopted more widely.

Research questions

The case studies concentrated their focus on a series of research questions, addressing key policy concerns relating to the use of ICT, the factors that can be shown to encourage appropriate use, and the implications of ICT usage. The research questions can be summarised as follows:

1) *What use did the schools make of ICT?* Schools may use ICT in different ways: the case studies examined how ICT was used within each school and their reported impact.
2) *To what extent was ICT a catalyst for educational reform?* Technology is often seen as an agent of educational reform, particularly in encouraging a student-centred approach to teaching and learning. The case study schools were asked to consider the extent to which ICT had been a catalyst for change.
3) *Which factors influence the adoption and use of ICT in schools?* In many countries, ICT has been adopted at different rates in different schools and by different teachers. Factors that encourage the adoption of ICT are obviously of keen policy interest. The case studies examined the factors associated with the adoption of the technology, and the patterns of diffusion of ICT usage through schools. Particular attention was given to the importance of infrastructure availability and teacher ICT skills.
4) *Did the adoption of ICT widen or narrow equity gaps?* Concern has been expressed that ICT may have benefits for particular groups of students, thus providing them with an advantage over others. It might, for example, have greater benefits for those with access to computers at home, appeal particularly to boys, or benefit the most able learners. On the other hand, some argue that ICT facilitates differentiated learning, allows students to work to their own ability, and motivates disenchanted students.
5) *What impact did ICT have on academic performance?* Appropriate use of ICT has been argued to increase academic standards through provision of a wide range of resources and more engaging learning experiences. Others have suggested that ICT may lower academic standards either as a result of the inappropriate nature of the resources available, or by encouraging a "cut and paste" culture inimical to real learning. The case studies examined teacher perceptions on these issues and in some cases collected objective quality data.

2. Case Studies of Innovative Schools

The series of issues under study related to ICT as an innovation within schools are elusive. Seemingly identical uses of ICT may have different outcomes in different schools. Factors such as student motivation are difficult to measure, yet vary widely under seemingly identical conditions. Small details in the context of a school may have important implications for the outcome of the innovation. The issues being explored are also complex. The study is concerned with the process of adoption of ICT within the school, with the way in which it is used, and how students react to that usage. Recognition of the complexity of the issues and the need to capture the subtleties of the context directed the research towards a case study approach. Consequently the study is primarily concerned with qualitative data, collected in interviews with principals, teachers, students and parents. Some quantitative data was collected including of teacher ICT practices, and in a few cases some student test scores, but the main focus of the case studies was on processes.

Site selection

Each country was encouraged to select 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. They may have been applied gradually over time or concentrated in a shorter time period. A further criterion was that innovations were school-wide, but could relate to any number of aspects of the schools operation. Innovations should have led, or had the potential to lead, to significant improvements in the quality of education, its costs, or in equity of access.

In most countries the sites were selected by the research team, but in a few cases the selection was done by a national agency. Site selection generally emphasised schools that were relatively rich in ICT and were perceived to be using these resources effectively. Beyond that, the detail of the selection process varied. 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. A few of the countries were also participating in the Second Information Technology in Education Study (SITES) Module 2[3] case studies, and selected schools that met the criteria for both projects.

The nearly-100 schools selected were not intended to be representative of ordinary schools. They were specifically selected as leaders in innovation and in the use of ICT. Hence this study is not about technology as used in ordinary schools but about the insights to be gained from examination of relatively successful innovative ones. While the schools were unusual in terms of resources and dynamism, they were not so different that they did not experience the pressures of curriculum demands, problematic staff skills and variety of student needs that are commonly experienced across systems. They are, therefore, indicative of issues that emerge in ordinary schools as ICT use develops.

Data collection

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.

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, where 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.)

For all significant issues wherever possible, triangulation was strongly recommended - 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 could be coupled with observation of the length of time required for teachers to respond to messages sent to them by interviewers and statements from parents and teachers on whether or not they communicate with teachers by e-mail,

[3] The Second Information Technology in Education Study: Module 2 (SITES: M2) was an international study of innovative pedagogical practices that use information and communication technology (ICT). The study was sponsored by the International Association for the Evaluation of Educational Achievement (IEA). Further details are available at http://sitesm2.org/

and if so, how effective this mode of communication is.

A further consideration for examining school innovations is that outside observers are often guided 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 - advisers, trainers, and the like. Similarly, where teachers are asked to identify students for interview, they tend to select highly articulate positive students. 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, and other relevant dimensions. Similarly, teachers and school administrators, because of their exposure to public view, are often careful to avoid stating opinions or reporting conditions that differ widely from what is mandated or publicly desired. In examining issues that are potentially sensitive, such as the degree of support for a particular innovation, interviewers were asked to probe beneath the glossier surface.

3. ICT as Innovation

The application of ICT in education refers to an array of technologies that can be applied in a variety of ways, not to a single approach. The case study schools amply illustrate the variety of forms that ICT can take in schools. Some of the schools had developed sophisticated intranets providing access to course information, learning materials and other resources. Students could use the networks to store and submit assignments, access the web and display their own web pages. Perhaps the most developed example was found in Singapore (SG01), where the intranet was used to store recorded lectures and provide a forum for discussions. Other schools used their intranets to provide access to parents or to link with local communities (US04 Pine City, and NL01 de Verrekijker). At the other end of the spectrum, some of the innovations involved relatively modest technology. In one Mexican school (MX02) a set of graphing calculators was used to encourage students to engage in critical reflection.

One of the striking features of these schools taken as a whole is the diversity of ways in which ICT was used, which can be summarised under four general headings:

- a) ICT as the focus of the innovation;
- b) Teaching and learning with ICT;
- c) Educational management with ICT;
- d) Extending the boundaries of the school.

a) ICT as the focus of innovation

In a number of the schools the innovation had begun with the need to develop ICT skills in the learners, itself driven by different factors. In von Neumann primary school in Hungary (HU03) a highly motivated principal saw ICT as an important skill for the future. In a junior high school in Austria (AT03, Grein), the drive was fuelled by concern over falling enrolments. Development of a high quality ICT programme was seen as a key element in attracting new students.

Although motivated by a desire to include the technology, the innovations in these schools often extended beyond the technical. In the Hungarian case the entire town was mobilised in the effort to introduce ICT so fully into the school. Local administrative structures were involved in raising funds, all of the teachers received training, and many went on to complete degrees in related subjects. Parents, even those with low incomes, began to buy computers for home use. As a consequence, the school established a national profile. Teachers have been invited to give papers at conferences, and to act as trainers in other schools. The students have been very enthusiastic, and have reached a high

standard of ICT skill. Teachers not involved in teaching ICT began to use it in their own subjects such as in Geography, Biology, Art and other subjects.

A similar broad impact was reported in a Danish school (DK03 Rugkobbelskolen), in which the innovation was the development of a school-wide ICT curriculum. This involved designing an ICT programme for each group of students, and developing methods to deliver that skill set in an integrated way. Not all of the teachers had sufficient ICT skills, and so the school began to experiment with team teaching. In the process the teachers began to engage in collaborative planning exercises and to work together in new ways. The staff feels the impact of this change. As one teacher put it "We are developing from an organisation of a very regulated and hierarchic structure into one consisting of teams which to a high degree are self-adjusting… but also teams reflecting on what we are really doing, discussing it between us and setting up new goals" (ICT co-ordinator, DK03, p6).

b) Teaching and learning with ICT

For other schools, the initial focus of the innovation was on teaching and learning. A US Junior High school (US06 Joshua) with a predominantly African-American population with high rates of poverty (80% of the students were eligible for a free or subsidised lunch) used ICT to facilitate the introduction of an inquiry-based learning programme. In this approach the Internet is a resource for students to find curriculum-related information, and then use open software to make reports, organise their work and express their findings. A similar aim was reported in a secondary school in the Netherlands (NL03, Jacobus). Here the innovation was a move towards self-study, facilitated by ICT. Teachers were given release from other duties to develop a series of student-centred activities. The school timetable was then adjusted to allow time for students to work in groups on these projects, with teachers acting as facilitators. Although the project did not make extensive use of the Internet because of poor connectivity, ICT was used to organise and present the work.

These two examples involved significant restructuring of school timetables and infrastructure. Other examples revealed more modest moves towards problem solving and students discovering or constructing their own understanding. In Mexico, one school began to use graphing calculators in the classroom, and found that the change resulted in a different pedagogy. As one teacher put it "Students generate their own knowledge, in other words, they build concepts which have not been previously given. Education is no longer like it was before; then, the student was a recipient and I was all the time giving out the information which the students had only to accept. This new method promotes reflection, critical judgement… it makes students improve their own operational abilities, it makes them carry out a thorough analysis of what they are studying" (Teacher, MX02, p5). A Greek school (GR05, p3) reported similar results with use of ICT simulations in science. In one example students used a simulation of a generator, and were able to adjust different parameters and observe the impact.

Even where ICT was not used to change the pedagogy, it had an impact on the motivation of learners. Many schools indicated that they had seen strong motivational benefits with ICT. As one primary teacher in Greece pointed out "it could probably be written on a piece of paper, but if it is done on the computer it is more entertaining, interesting, giving the students a different taste of action" (GR04, p6).

c) Educational management with ICT

A very different use of ICT is for educational management. An example was found at Highgrove School in the UK (UK02), in which the innovation was the development of a comprehensive school database. The aim was the allow staff to review student performance easily, thus ensuring that under-achievers could be easily identified. As part of the innovation, students were encouraged to monitor their own progress against personal targets, set in consultation with the teachers. The students interviewed felt that they were helped by having clear information about their performance, and the school reported students taking more responsibility for their own learning.

d) Extending the boundaries of school

ICT was also used in the case studies to extend the traditional boundaries of school. In Westwinds College, Canada, the innovation was an ICT-based open learning programme which allowed students who had left school to take courses part time and complete examinations (CA11, p11). In another Canadian school the aim of the innovation was to meet the specific needs of an increasing number of students from developing countries (CA04, Spencer, p2).

ICT was also used to engage parents and the community more actively. In a British junior school located in an economically disadvantaged area (UK03 Littlejohn), the aim was to create a learning community: parents were offered ICT training, childcare facilities were provided to facilitate attendance, and laptops were provided to students for home use. These ICT initiatives were part of a wider scheme aimed at encouraging students and parents to become involved with the school and with learning.

Software applications in the case study schools

As might be expected from the range of uses of ICT, the applications also varied widely. For most schools, the most common applications used were "open tools" - software applications without any particular didactic content, but which allow students to develop their own work. The most familiar of the open tools is the word processor, but spreadsheets, graphing and drawing programmes, search engines, and presentation programs such as *Powerpoint* are also in this category. There was relatively little use of database programmes, despite their importance within the field of information technology.

Many schools used the Internet as a resource, either for teaching materials or as a resource for student research. As one Greek principal said, "Through the computer the knowledge is extended. There is a much bigger amount of information" (GR05, p5). A few of the schools were using the web to publish student project work, providing the added motivation of a real, and sometimes large, audience. E-mail was widely mentioned although a few schools still had no e-mail accounts for students or teachers (e.g., AT01, Steinbau). Other applications included discussion forums and videoconferencing.

There was some use of didactic software in the case study schools, often based on a "drill and practice" methodology. In one Irish primary school (IE02), most of the ICT activity involved the use of educational software, including a mix of drill and practice titles and some more open software. Few schools reported using the more advanced forms of didactic software, such as intelligent tutoring systems, or integrated learning systems (ILS).

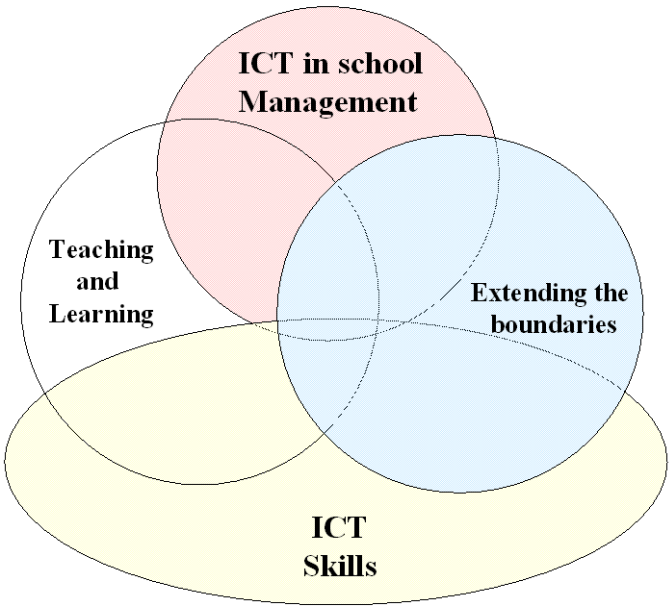
For most schools, the use of ICT was a mix of the applications outlined above. The pattern of usage, however, varied considerably. In the USA, a middle school (US03, Mountain) reported that about 75% of all software used by students and teachers was tools. In Finland, a lower secondary school noted that word processing was the software most familiar to teachers and the software used most often in class. The second most popular application was the use of the web, with a third of teachers using it at least weekly. There was also significant use of educational software, often drill and practice programmes (FI04, p7). A small number of schools made much more extensive use of software, including primary schools in the Netherlands and Ireland (NL02 and IE02) and in a second level school in the UK (UK01).

In sum: ICT as innovation

These case studies do not support the perception of ICT as a single defined direction for development. The spectrum of uses of ICT in schools can be categorised under four headings relating to its main aim: ICT skills, teaching and learning, management, and extending the boundaries of school. These four categories are not mutually exclusive. Many of the schools had initiatives in more than one of these categories. In von Neumann School in Hungary, for example, the innovation had begun with a focus on ICT skills, but had spread to include the use of ICT in teaching a range of other subjects. In

Rugkobbelskolen (DK03) the initiative had begun with a need to deliver ICT skills, but had resulted in team teaching and collaborative planning by teachers.

Figure 1. Typology of innovations with ICT



Nor are these categories entirely distinct. In Highgrove School (UK02), ICT was used to track student progress and provide continuous data to teachers, students and parents which may be seen as a management innovation but it also has an impact on learning. Many of the schools had initiatives that could be considered to fall into more than one category. There was a particularly strong overlap between teaching students ICT skills, and the uses of ICT in support of teaching and learning and extending the boundaries. While many schools began to teach ICT skills in isolation, the more ambitious among them had extended the use of ICT into other areas.

4. The Contribution of ICT to Educational Change

One of the central concerns of this study is the role of ICT in educational change, given its common association with new methods of teaching and learning and a student-centred approach. Some expect ICT to promote increased collaboration between teachers, thus developing and sharing good practice. These case studies provide an opportunity to examine the relationship between the adoption of ICT and the educational reform in more detail. In doing so, a key question is the extent to which ICT acts as the change agent.

ICT linked to change in some schools but not others

Several of the schools studied reported that ICT had led to changes in pedagogy within the school. In Greece, a relatively affluent primary school (GR01, School A) introduced ICT as part of an effort to improve students' thinking skills. According to the deputy principal, technology use led to collaborative work among students, which then led to the teachers deciding to change their ways of teaching so that students now work more autonomously. In a secondary school in Finland (FI04

Lansimaki), a very similar outcome was noted. The use of ICT led to more student-centred learning, and students became more active in collecting, processing and constructing information. Authenticity became an important component of learning content; students became more responsible for their own learning processes. In another Finnish school, the researchers reported that "ICT is changing the way teachers teach" (FI02, p8). In Mexico, a secondary school experimented with graphing calculators. A teacher reported that "it makes me modify all my programmes, because... one activity generates a whole set of other themes which I cannot see as something apart. On the contrary, I must integrate those activities into my programme and most of the time it means that I have a lot more work to do (Teacher, MX02, p5).

In some cases, it was the use of the Internet as a research tool that was seen to have an impact. A Canadian student described the benefits in these terms: "In every class you're doing research. English, you're researching a bunch of stuff. History, researching a lot of stuff on the presidents, prime ministers, wars and stuff like that... they're a great help, because they are so accessible in our school" (CA01, p5). Similarly, in a Mexican High School, the Internet was seen as propelling collective work, information exchange and encouraging a variety of different perspectives and understandings of the same theme (MX03, p5).

The Internet was also important for one of the Italian primary schools (IT03, Rodari). It had 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 projects (e.g., KidsLink), and to regular computer communications by students. The research team saw ICT as a support for making learning more fun, with communication still a major school focus. Over time teaching became more student centred and the classroom has become connected to the rest of the world.

While the above examples support the idea of ICT as a catalyst for educational change, there were other cases where it did not appear to have acted in this catalytic role. In Luxembourg, the researchers dismissed the idea, saying "ICT is a resource like any other and not a catalyst" (LU02, p21). The Greek schools provide further cases where ICT did not trigger educational change. In one Greek secondary school, most teachers used ICT to complement their traditional lessons, either by providing ways to manipulate the information, or by making the presentation more attractive. Most teachers "did not escape" the traditional teacher-centred model (GR05, p6). In one primary school, they made use of more materials, but "could not avoid returning to the traditional teacher-centred teaching model" (GR04, p7). In another Greek school, teachers said that they found ICT useful as a supplement to conventional lessons, expressed by one thus: "I consider it is necessary. But I insist on the teaching of the unit first, I do not go directly on the computer" (Teacher 1, GR03, p6).

There are thus different approaches and impacts - in some schools ICT was identified as responsible for a significant shift in teaching and learning practices while in others it is seen as reinforcing traditional methods.

ICT enabling change

There is then a third group of schools, which noted significant changes in pedagogical practices with the introduction of ICT, but argued that it was an enabler not the driver of the change. Aurora Primary School in Finland was such a school. It had engaged in a series of activities which could not have been done without ICT but they argued that the driver was the desire to improve educational quality rather than the technology *per se* (FI01, p12). Similarly, in a Finnish secondary school, the teachers felt that their pedagogy was not particularly technology-led, even though many used ICT to support project-based and collaborative work. They suggested that it is difficult to separate the use of technology from the overall pedagogical orientation of the school (FI03, Kupittaa, p6). A Canadian

teacher expressed the same sentiment: “In my own classroom it is an integral part of the academic content only because I chose to make it so. I could certainly teach much of what I am teaching without any technology, but it is not the same experience” (CA01, p6). In one Irish primary school case the focus of ICT usage was on a range of software products which was seen as facilitating more student-centred activities. However, the school was also using a school play, music and other activities to provide opportunities for student-centred learning, and so again the use of ICT was consistent with the existing orientation of the school (IE02).

These examples suggest that ICT is an enabler of change where the change is consistent with the orientation of the school. This view places teachers and their beliefs centre stage, with technology in a supporting role. This view also provides a lens with which to review the cases where ICT appeared to cause educational change: in some of these, ICT adoption coincided with other factors that may have influenced the pedagogical beliefs in the school.

ICT as a lever

More autonomous student work and collaboration were reported in a Greek primary school (GR01, School A) as ICT was introduced. In this instance, 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 the changes in pedagogy were associated with the introduction of technology, it is apparent that the changes were being guided in this direction by the university team. In this sense, ICT was a “lever”, used by a university research team to drive the school in a predetermined direction.

A further such example came from Japan, in a junior high school (JP01, Utase) in a newly-constructed city in Japan. Radical departures from conventional educational procedures were instituted when the school was built in 1996 with the aim of encouraging students to be more creative and independent thinkers and learners. The school was designed around subject centres - classrooms specialised in a particular subject - where resources would be readily available during class. The school rules also reflected the culture of encouraging students to take more responsibility for their own learning, with no uniform nor bell to announce the end of class. Instead, students could choose their own clothes and were expected to move from class to class at the appropriate times. Use of ICT was an integral part of this innovation. The subject centres were equipped with computers and projection equipment to facilitate information access and presentation. Although ICT was an important part of the innovation, it is clear that it was not its origin.

ICT can also be seen as having operated as a lever in a large public high school in a small town in Portugal (PT02, Póvoa do Lanhoso). As a result of the opportunities offered by a Ministry of Education Internet programme, the school management body set out to introduce a new curriculum with associated teaching and learning methods based on ICT. The management team thus recognised the potential that ICT had as a lever for curricular and instructional change, both of which were the original goals. Similarly, in Israel a large religious elementary school (IL03, Neot David) used ICT as a lever to create learning communities for teachers and students. The long-term goal was to develop independent learners, with learning communities as organisational mechanisms adopted for this end.

In many of the case study schools, ICT was part of an innovation that was planned either by the school staff or by a higher administrative body, such as a ministry. For example, one high school in Israel deliberately adopted technology as a “means to create innovative pedagogy” (IL01, Olem Shem). In a few of these cases, ICT, once implemented, served as a catalyst for further changes. Two examples are Bendigo (AU01) and Glen Waverley (AU02), both public high schools in Australia. Both schools, in reaction to state educational objectives, had decided to shift their curricula to be project based, emphasise student autonomy in learning, and move from being teacher-centred to teacher-guided. The potential of ICT influenced some decisions but the primary emphasis on student autonomy was an academic decision, not one driven or initiated by the technology. But once it was integrated into the lives of these schools, ICT opened further opportunities for innovation and change.

A staff member at Bendigo (AU01) 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 two Danish schools (DK03, Kerby and DK04, Rugkobbel), where the process of implementing ICT became a catalyst for other school changes.

In Santa Maria High School in Mexico (MX03), a computer network was developed as part of a community-based programme that included high school education, community development, and craft training. The network once installed, 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.

These examples suggest a view of educational change as an on-going process. Frequently, ICT was part of the process, enabling the change and sometimes encouraging further change. In these cases the use of technology may be characterised as a lever, as it was deliberately used to give an additional impetus to an existing drive, and sometimes additional unintended changes also flowed from the adoption of ICT.

External influences

There were external factors at work in the process of adoption of ICT in some of these cases which may not be present in the majority of schools. Some of the case study schools were closely associated with universities, making it difficult to determine whether the educational change was a result of the technology or the engagement of the university. These include Oulu in Finland (FI02), which "supports and complements research activities of the faculty of education [University of Oulu]" and ESANS in Mexico (MX01), which is a pedagogic laboratory for the Superior Normal School to which it is attached.

Many of these schools were at the leading edge in their countries as a result of involvement in pilot projects. Participation in such projects has implications in addition to providing the funding for equipment and infrastructure. Projects often place demands on schools, and impose reporting structures and deadlines, which may help to drive change. In some of these cases, ICT also had a symbolic value which helped to change parental attitudes about the schools or which made the school more attractive to staff and students. Participation in a Hungarian ICT project, for instance, was a motivator in Von Neumann School, which established a centre of "cutting edge technology" in a rural area. The "whole learning and teaching climate of the school changed" as almost all teachers became involved with this new technology - it was a "very strong catalyst" (HU03, p18). In the UK, Littlejohn School was provided with funding for technology in a disadvantaged community. The principal noted that parents "feel complimented that someone asked if they would like access to top quality technology" (Principal UK03, p9). Teachers and students were also influenced by the promise of a laptop for home use. As one teacher explained, "teachers have been forced to re-evaluate how they are doing things and pupils have had to adjust to using a new tool and the expectations of taking a laptop home" (Teacher UK03, p7).

External project funding, links with universities and the presence of impressive technology all place additional pressure on a school to make good use of ICT. Innovative ideas are more likely to be carried through to fruition in the context of these external pressures. This has implications both for the replicability and sustainability of some of these initiatives. If change has been driven by pressures from an external project or university team, this raises a question about whether this change can be sustained once these external factors are withdrawn. Similarly if change is encouraged by the symbolic effect of involvement in a leading edge project, this may be difficult to replicate on a wider scale.

In sum: catalyst or lever?

This section began with the central question of the role of ICT as a catalyst for educational change. The findings with relation to this question are mixed. A minority of schools report that ICT has had little impact on pedagogical practices and traditional methods remain dominant. However, the majority of schools see ICT as associated with a change in pedagogical practices. In most cases where a change was observed, there were existing factors orienting the school towards the change. These took a variety of forms. Sometimes the pressure came from a concern about standards, or a need to reach a disadvantaged community. In others, it came from a funded project, collaboration with a university, or a decision by management. In certain cases, the introduction of technology had, of itself, sparked a change in pedagogical practices, but these were few in number. This study offers little to suggest that ICT acts primarily as the instigator of educational change.

A lever, on the other hand, amplifies, empowers and enables an existing pressure. There is ample evidence to indicate that ICT can be used to enable activities that could not have been done otherwise or to facilitate tasks that would have been more difficult without it. In addition, the strong motivational power of ICT seems to have added additional leverage - in its attraction for teachers, students and parents. On this view of ICT, the technology is value-neutral and adaptable to many uses. That flexibility which has made it ubiquitous also means that it can be adapted as easily to support teacher-centred instruction as for student-centred methods. As the Norwegian summary report concluded, ICT can support a traditional didactic model of teaching as well as a project-based model. There is nothing inherent in the technology which orients it towards one particular methodology.

The catalyst/lever distinction is significant for policy. If ICT is a catalyst, then the provision of equipment and infrastructure can be expected to lead to an increase in student-centred teaching. However, if ICT is a neutral lever, then the crucial factor in determining the direction of change will be the thinking of the teachers who use it. As one report from Greece put it, "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 for such approaches, facilitated though by the computer use."

5. Factors influencing the Implementation of School ICT Strategies

While the teaching of ICT skills within schools is relatively unproblematic, the use of ICT in support of better teaching and learning of other subjects has been disappointing in many countries. Its educational use has varied widely and despite the impressive progress made by some leading schools, it has made little impact on teaching in many others. Policy-makers and educational leaders have a keen interest in the process of adoption of ICT, and the factors that help it contribute to worthwhile educational innovation.

In the case studies, the researchers were asked to focus specifically on the questions of how ICT was adopted in the school, and which factors facilitated this innovation. In particular, they were asked to assess the importance of technical infrastructure, relevant staff competence, and student ICT skills. As the schools were typically in the vanguard within their countries, they provide interesting insights for those wishing to encourage wider innovation with ICT.

Processes of adoption

For most of the case study schools, the adoption of ICT was not a single step, but an ongoing process. Teachers did not adopt ICT simultaneously, but its use spread gradually through the staff. A typical example was Biever (LU02), a technical high school in Luxembourg. The first teachers involved with computers were a small group of mostly male mathematics and science teachers, motivated in the 1980s by an interest in computer programming. Later, word processing attracted a wider group of staff, including language teachers. Internet access in the mid 1990s was an incentive for a larger

group of teachers to become computer users. At the time of the study, 70-80% of the teachers used ICT either for preparing their own work or within classroom instruction. There remained, however, a minority of teachers who did not use it. Gradual adoption was also found in primary schools such as Aurora in Finland (FI01, p13), where a small number of teachers were initially enthusiastic, ICT use then spread to include the majority of teachers, leaving a few not using it. Even where ICT use was well developed, most schools reported that some teachers chose not to use it.

Once most of the teachers were using the technology, however, the schools sought to devise ways to accommodate the reluctant users while still providing ICT experiences to all students. St Sheila's, an Irish primary school (IE02), reported a typical pattern. The use of ICT began with a small number of enthusiastic teachers. Later, training was provided for staff, the use of ICT was incorporated into school structures, and most teachers began to use it. However, there remained a small number of teachers who remained outside, and they were allowed to swap classes with other teachers to avoid ICT time.

The adoption of ICT is thus a complex process of innovation. In most schools the teachers retained the freedom to adopt or reject ICT, even when its usage was encouraged by school management. Thus the integration of ICT into teaching involves its adoption by each individual teacher in the context of his/her own subject. The case studies highlighted a series of issues that appeared to be significant factors in encouraging this process. The differences appeared even within countries. An Italian school (IT01, Einstein) found that use of ICT correlated with teacher technical ability, a second (IT04, Tosi) stressed the infrastructure. This variation suggests that there is no single determinant factor: ICT adoption is a process dependent on the presence of a series of ingredients. These ingredients are present to different degrees in each school and hence different factors can serve as the limiting variable in the process of ICT adoption.

Infrastructure and teacher factors

Equipment

> "I think you have to have the infrastructure in place so that people don't get frustrated" (Principal, CA04, p6).

Access to adequate technology is clearly a prerequisite for successful adoption. One school in Mexico reported very high levels of integration of graphing calculators, but much lower levels of integration of ICT generally, mainly because of lack of access to the computer room (MX02, p7). With limited resources, some schools have given first priority in access to computers to their ICT skills courses, often leaving other teachers with little or no access (NL03, Jacobus). It was noted in a Luxembourg school that ICT could be used in any subjects if the computer labs were free, but that in reality they were very rarely unoccupied (LU02, p8). A Finnish school (FI03, p7) identified as a key factor in the use of ICT was that there should be sufficient computer rooms to ensure that subject teachers were easily able to get access when they wanted it.

Schools, even those reporting successful use of ICT, report very different levels and configurations of technology. One Norwegian school (NO02, Royse) had a ratio of two students per computer, a wireless network, and a student body who almost all had computers at home. A second school in Norway (NO01, Ringstabekk) in contrast reported 18 students per computer, and almost all of the computers were in a room where teachers had to reserve time to get access. Students were not allowed in the computer room unless teachers were present. At the time of the study, the student-to-computer ratio in the case study schools ranged from 2:1 to 26:1. Sometimes, even where the level of equipment appeared high, some of the computers were quite old. In Israel, one school (IL02, Cramim) had a ratio of seven students per computer, but all of the computers were over six years old. In Finland more than half the computers in one school (FI02, Oulu) were considered obsolete. In most schools, equipment was under-funded, often composed of a mixture of old and new machines that made maintenance and software updating difficult.

Many schools obtained a significant number of their computers through one-off funding, often either an infrastructure grant through the national or regional educational authority, or a corporate donation, and had no regular budget for equipment replacement. One school in Germany, for example (DE03, Albani), received a one-off grant of new equipment as a World Exhibition School. Only a very small number of schools had arrangements in place for the renewal of equipment. An example was provided by Norway (NO02, Royse), where the local municipality provided the school with an ICT grant equivalent to 8% of the school's total budget. Another was in Luxembourg, where the national educational authority replaced computer hardware and faulty equipment every three years.

These cases were the exceptions, however. Most schools were resigned to no reliable source of future funding. In some, equipment purchases were supported by parental contributions. Such difficulties with equipment provision is underlined more starkly when it is remembered that these were often the pilot schools and better funded than most. As put by one Germany school (DE05 Stein), "on the whole those interviewed described the computer equipment as not so good but, in comparison to other schools, above average".

Internet connections

Access to the Internet is of particular importance for schools. By providing access to the resources of the web, Internet access can facilitate learning activities centred on student research. Internet access enables a whole range of communication activities, including links with other schools, parent access, and distance learning. For many of the case study schools, Internet connectivity was a *sine qua non* of their ICT plans. At the time of the study, there was considerable variation in the Internet connectivity of the schools. In 40 of the cases, all of the computers were connected, but at the other end of the spectrum a primary school in Mexico (MX04, Quiroz) had only one computer with Internet access.

The educational use of the Internet was also associated with the quality of the connection. At the time of the study, many of the schools were using dial-up Internet connections, which were seen by some as unsatisfactory. In a primary school in Finland, the use of the Internet in teaching had actually declined as teachers had become frustrated with the speed and reliability of the connection: they felt that "the advantage is not worth the effort" (FI01, p8). Teachers in a Netherlands secondary school had adopted a project-based approach, but those who developed the projects tried to ensure that most of the information needed could be found in encyclopaedias and other sources through fears about the reliability of the Internet access. They also arranged that students would not be offered two projects involving the Internet in one term so as to minimise the disruption caused by the unreliable connection (NL03, Jacobus, p10).

In general, Internet connectivity was greater in the schools with older students. In Portugal, for example, about 90% of all schools above grade 3 (cycle 1) had Internet connections at the time of the study compared with 10% of those for grades 1-3. This may reflect funding patterns for primary schools, but may also reflect concern about the educational value of Internet activities. Some teachers, particularly in primary schools, expressed concern about the ability of their students to use the resources on the web meaningfully. Teachers in Aurora school in Finland (FI01, p8) indicated that much of the work using the web amounted to mechanical information-copying: they maintained that the web was often used to search for information on specific and fragmented questions and did not involve any information-processing. They did note some activities with the web that involved deeper inquiry, seen as the ideal but relatively rare.

Technical support

ICT use was further limited by problems with technical support. In most schools, technical difficulties were reported as a major barrier to usage and a source of frustration for students and teachers. A technical school in Luxembourg stated that "technical problems remain a serious deterrent" to ICT use. "The technical problems that arose were much more difficult to solve than… envisaged. Also the school lacked permanent technical staff to solve these general maintenance and technical problems, so that computer teachers found themselves overwhelmed with this responsibility as well as

teaching". (LU02, Biever). A Canadian student said "Our system is down maybe once a month. When the system goes down, the school pretty much shuts down" (CA01, p5). Technical difficulties were also a deterrent to teacher use, confirmed by a Canadian teacher, "I think resistance to technology has occurred because of frustration of the effectiveness of the machines… half the computers don't work, or the printers don't work. After that occurs numerous times, people stop using them. They can only tolerate so much of that". (CA04, p5)

Few schools described satisfactory schemes that brought industry standard responses to equipment or software problems. Reference was made to the situation in Vienna as an example, which at the time had a city-wide hardware repair scheme where responses to calls required up to two days and the actual repairs averaged almost 14 days. Although the schools had full-time technicians, they were charged only with software support, and were not allowed to repair equipment or make changes on the server (AT01, Vienna). There were reported problems with technical assistance across the sites in Denmark, too. One school, (DK01, Hjortespring), described slow response times for assistance and almost a third of its 225 computers regularly out of order.

Inadequate technical support was often tolerated at the personal expense of a teacher or technician who bore the burden of this task, as with the teacher who usually took an "eight minute lunch and no breaks". As well as placing a burden on the person involved, this pattern has detrimental effects. Maintenance frequently diverts ICT support professionals from educational duties to technical maintenance tasks, as described in a school in Singapore, "if anything breaks down, the focus is not on teaching but [they] have to troubleshoot". (SG01, p11) Similarly in Golden High School, Canada, the site administrators found themselves doing a lot of technical support, when they could have spent their time more productively on curriculum support. (CA01, p4) Where technical support was provided by an enthusiastic teacher, this built an unhealthy reliance on that person, and a vulnerability to staff turnover. In one Irish primary school, all of the teachers interviewed commented on their dependence on the skill of the ICT co-ordinator (IE02, p2).

Where formal arrangements were in place for providing technical support structures varied widely. Some schools made some reductions to a teacher's workload to allow time for technical work. In Aurora school in Finland (FI01), a class teacher was given responsibility for the maintenance of the computers and was released from teaching for one hour per week to do this, (which was regarded as insufficient). For more serious problems, a specialist provided by the city authorities could be called, seen as insufficient and too slow. In Freiherr School in Germany (DE05), a teacher was released 4 hours per week. But asking a teacher to do technical work is not always satisfactory, as one reported, "The main problem is that we have no-one who really masters it, and everything takes so long to do… It is frustrating when you want to do something and the computer doesn't work". (Teacher, DE05)

By contrast, in Harland (US02) two full-time technical specialists were hired to support 56 teachers and the ICT infrastructure, and at ESANS (MX01) a four-person team was responsible for the media area and equipment maintenance. At Kerby in Denmark (DK03), technical assistance was provided through a combination of the school's own ICT co-ordinator and an effective municipal data department. In a few schools (e.g., KO01, Banghwa, NL01, De Verrekijker, NL02, Marke) parents provided some of the support, either through installing networks, maintenance of Web sites, or assisting teachers with technical problems.

Despite the variety of structures, the overwhelming view was that technical support was both inadequate and a major barrier to the development of ICT use in education. The US corporate standard of a full-time technical support person for every 50 computers was way beyond the reach of most schools. Yet, it can be argued that ICT in schools is more time-critical than in many corporate environments - a delay even of a few minutes at the start of a class period may often lead to a teacher cancelling the entire component and reverting to a fallback plan. The rigid schedule of schools, particularly at secondary level, leaves little margin for delay. Unless schools have a reasonable level of technical support, it is not realistic to expect teachers to rely on ICT for their lessons. The Austrian country summary concluded thus, "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)

Teacher skills and attitudes

While infrastructure issues such as access to equipment, reliable Internet connectivity and adequate technical support were important components of the equation, ICT use was not determined by infrastructure alone. Some very well-equipped schools found that few of their teachers made use of it. Athenee School in Luxembourg (LU01), for example, had a ratio of seven students per computer, but reported that teachers were reluctant to integrate technology partly because out of fear and partly because they preferred traditional teaching methods. Other schools had poor infrastructure and yet found teachers making use of the technology. ICT was widely used by teachers and students in Ringstabekk School in Norway (NO01), although the school regarded its infrastructure as insufficient with a ratio of eighteen students per computer at the time. In the UK, all three case study schools had technical problems, but made progress in spite of these (UK00, Summary).

Recognition that adoption of ICT requires more than infrastructure has led to a focus on teacher readiness which may be understood as two distinct strands. First, teachers need sufficient ICT skills to make use of the technology and to feel confident enough to use it in a classroom setting. Second, teachers require insights into the pedagogical role of ICT, in order to use it meaningfully in their teaching.

In most of the case study schools, there remained some teachers who did not use ICT. In a Greek secondary school (GR03, p7), despite the stimulus of an external project and a school-wide policy of ICT usage, there were some who did not take it up at all. In Oulu school in Finland (FI02, p9), the teachers using ICT were very happy with the progress, and saw learning gains in deeper understanding, but they found it difficult to convince their colleagues of the benefits. This reluctance was often attributed to lack of technical skill. In Ireland, for example, it was noted that the teachers who did not develop sufficient confidence avoided using ICT (IE02, St Sheila's). Different aspects of teacher technical skill and confidence were identified by several of the Canadian teachers. One in a primary school said, "I think that they are just afraid because there hasn't been the professional development… Resistance is a genuine fear, not an attitudinal thing." (CA04, p5) Others highlighted the impact of technical problems on inexperienced teachers, saying "they've sort of been overwhelmed with software or hardware glitches that have shown up". (CA04, p2) Lack of technical skill may make teachers reluctant to use technology in front of students: in a Canadian secondary school, some teachers admitted they were reluctant users because they would be embarrassed that the students knew more about the technology than they did (CA11, p4).

For other schools, the barrier was perceived to be less teachers' lack of skills and more their inability to see its educational potential. A Canadian school reported "I think that we have teachers who just have not had an opportunity to see how to integrate it" (CA04, p5). A Finnish school (FI03 Kupittaa, p6) concluded that ICT skills could not be the main determinant of usage, as many of the first teachers to adopt ICT did not have any better ICT skills than other teachers. In another Finnish school, little variation in teacher ICT skills was observed but only half of the teachers made use of it (FI02, Oulu, p4). In a Mexican school (MX02, p4) half of the teachers made regular use of the computer room, even though many of them did not have much experience of ICT (MX02, p4). In a secondary school in Greece (GR05, p2) it was argued that ICT skill training was sufficient to familiarise teachers with the technology, but not sufficient to make them feel competent to integrate technology in their teaching. In one Finnish school (FI03, p7), teachers stressed that "teachers' integrating skills" were a prerequisite for use, and such stress on the pedagogy of ICT usage may run counter to initial expectations, while in another (FI04, p11), some teachers expressed surprise that the introduction of ICT involved so much of a pedagogical focus.

Teacher attitudes toward teaching and ICT also feature in the implementation equation. A Japanese school (JP01, Utase) reported that a number of teachers were sceptical of the value of ICT for their

subject areas and therefore made no attempt to integrate it into their teaching. In Korea, (KO01, Banghwa) the teachers most negative toward ICT saw it primarily as a tool to make their work easier while the most positive regarded it as support for higher level cognitive frameworks. The use of ICT is thus influenced by teacher beliefs about the appropriate role of the technology in education.

Professional development for ICT use

Almost all of the case study schools reported some related staff development activities. Most schools had at least some component of basic ICT skills training, recognising the lack of experience of some of their staff. As the vice principal in a Canadian school said, "we realised that there are many people on the staff that may have never touched a computer… so we had low-level training" (CA01).

Beyond basic skill training, schools had used a variety of structures to provide further professional development. In von Neumann, Hungary (HU03), teachers were encouraged to take part in training courses external to the school. Those who gained high-level qualifications in this way (such as a computer science degree) received a free computer for home use, plus an ICT pay supplement. Nearly a third of teachers in the school completed a degree in ICT, in addition to their existing qualifications. A school in Canada (CA01, p8) encouraged staff to take responsibility for their own training needs. The technology co-ordinators developed a checklist for staff who were able to identify their own training needs and had the option of attending mini training sessions during lunch (lunch bag professional development) or after school. (CA01, p8) Many of the schools used peer-tutoring systems, where experienced ICT users were encouraged to act as mentors to teachers with less experience. Littlejohn School (UK03) used experienced ICT teachers to act as trainers and mentors for others, and gradually reached the point where all teachers were users. In Aurora school (FI01), two teachers were appointed to act as "ICT pedagogical guides", both released from 6 hours of teaching duties per week to help colleagues to make better use of ICT.

Most of the Danish schools used similar in-school development models. At Hjortespring (DK01), a specific ICT project led to the project teachers with good relevant skills assisting other teachers as they began to use it. An informal network developed among the teachers, centred on a room designated for teacher preparation, which helped to create a secure environment for exploring ICT in teaching and to ensure relevant and timely support. A school in Singapore (SG01) used a two-tier model for staff development in the context of putting course material online. A core group of teachers were trained in depth on authoring tools and other Web-based technologies, and also given training in its pedagogical applications. They then took responsibility for making web-based learning materials for other teachers and encouraging colleagues to use the online system.

Despite the importance of professional development, schools noted weaknesses in this regard. Participation in training was often voluntary (e.g. MX02, p8) and reached mainly those with an existing interest in ICT. In some cases, the training was not provided in the school (for example, in Marie Curie School in France (FR01) with teachers required to go outside of the school to learn ICT skills).

Time for professional development was reported in many to be a problem. One Mexican case (MX04, Quiróz), indicated that professional development was neither provided within the school nor was time off available to attend classes outside. In the past, the state administrative authority had 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 programme nor was it guaranteed to continue. Other schools also stressed the importance of funding for release time. As the principal of a Canadian school said: "…professional development is going to be critical and providing teachers with the kind of release time that allows them to participate in the professional development. If you don't get that, it's going to do nothing, it's going to remain at that superficial level" (CA04, p6). In yet other places the staff development provided was considered by the teachers to be insufficient and too theoretical (PT04, Cabrieros). Teachers at a Korean school (KO01, Banghwa) found an "inconsistency between the ICT training and its application in the classrooms."

Balancing skills and infrastructure

A series of important factors in the process of adoption have been identified, some technical, others relating to teacher skills and attitudes. The schools varied in the importance they attach to each of these. This variation may reflect the uneven provision in the schools: a school that is well equipped may consider ICT skills as the major factor, while one that has just completed a staff development programme may consider infrastructure the barrier. The relative importance of these factors is also related to the phase of implementation. A Finnish school (FI04, Lansimaki) pointed 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.

The balance between the factors may also depend on the type of use to which ICT is put. Where it is central to the functioning of the school, reliability becomes paramount. A Singapore school (SG03) put infrastructure in first place - ICT was used primarily for communications, and so when the technology failed, the effect on the school was very serious. Another two Singapore schools (SG04 and SG05) saw staff competence as the main factor in implementation: the teachers made web-based support resources so if the technology failed, they could continue to teach and the reliability of the infrastructure was less critical. These factors may also compensate for each other as in a Finnish school (FI02, Oulu), where it was reported that good technical support reduced the need for strong teacher ICT skills so shifting the focus to the ability to integrate ICT into teaching.

Student ICT competencies

If ICT is to be used to support teaching and learning activities, then it might be expected that students also require a certain minimum level of ICT skill. If they have a very poor base, it might be expected that teachers would find the burden of supplementing basic skills a barrier to ICT application in their subjects. Hence it might be supposed that a basic level of student ICT skills would be a key enabling factor in ICT adoption. The case study schools offer little to support this hypothesis. Only nine of the cases indicated that student skills were important, and none of these considered them a primary factor. A Finnish report concluded: “of course students’ ICT competence is also an important factor, but if a teacher is skilful enough he/she can guide and support every student’s development in his/her own level” (FI03, p7).

One of the few exceptions was in Singapore where one school (SG02) introduced an e-learning platform. As online material was provided for students, a basic level of student ICT skill was required before the system could function. As they began to make heavy use of ICT for communication and even submission of assignments, teachers were drawn into increasing use as well. The school reported that the students’ enthusiastic adoption of ICT was a major driver for staff to follow suit.

There were other schools where the students with high levels of relevant skills were used to facilitate the overall development of ICT in the school. In one example in Israel (IL01, Ohel Shem), students were the Web masters. In examples from Norway (NO02, Royse) and the USA (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. Students were also used as a source of technical support as in a Mexico case (MX01, ESANS) where they were often called on by teachers for technical assistance. There were reports of students being trained to upgrade and maintain the computer equipment in Denmark (DK02, Korinth) and Germany (DE01, Bonn-Beuel, DE04, Jules Verne, and DE05, Freiherr). Co-opting students for this may have benefits beyond the provision of low-cost technical support: their motivation and status may so be enhanced, making school in general more attractive.

Other factors behind successful implementation

Schools mentioned other factors as influential in ICT adoption. Leadership emerged as one of the key issues, with a number of schools noting that the drive provided by the school management allowed

other difficulties to be overcome. A Mexican primary school attributed the introduction of ICT to a principal who did not have technical expertise herself but, despite this and unsupportive district officials, she identified ICT as a priority, built up the infrastructure, and encouraged staff to adopt it (MX04, p3). Similarly, a Canadian school suggested that a clear vision was more important than extensive infrastructure. The ICT co-ordinator in Spencer school argued that "if the school leadership has a vision for the use of technology, and can get staff to share that vision, the innovation can be carried out with available technology." (CA04, p8).

Another further factor of note was the presence among the staff of an "ICT champion". In some of the schools, much of the development was attributed to the energy and drive of one particular staff member, often a keen ICT enthusiast and a supporter of colleagues to the extent of providing direct training for them. In Park Garden primary school (CA03, p7), for example, the technology teacher provided much of the school's professional development during lunch hour and after school. In St Sheila's School, Ireland, a strong ICT enthusiast on the staff provided both training and technical support for colleagues (IE02). In other cases, the ICT champion provided a model of ICT use and did the preparatory work, such as in Aurora School, Finland (FI01, p15).

The curriculum can also prove to be a powerful factor. Particularly where high-stakes examinations are in place, the curriculum has a strong role in steering the nature of the educational activity. Some countries reported that appropriate use of ICT was actively encouraged in curricular documents. In Canada, a member of the education board pointed out that "ICT doesn't drive the curriculum, but in the last while, we haven't written any curriculum that doesn't include an activity to be done on the computer, or suggestion that it be done this way, on the computer. And every document out of the Ministry of Education now has references to how you can use the computer" (CA01, p6). Highlighting the potential of ICT within the existing curriculum is just part of the solution - if the aim of ICT implementation is to facilitate more problem solving and enquiry-based learning the curriculum may have to be adapted to re-focus on these aims. Relevant examples came from Australia where, in response to State educational objectives, both of the case study schools (AU01, Bendigo and AU02, Glen Waverly) had shifted their approach from being teacher centred to teacher guided and project based and to an emphasis on student autonomy in learning. Where education systems have examinations involving recall of a specific body of facts, the implementation of a student-centred educational reform using ICT is more problematic as reported in Kupittaa school in Finland, which blamed a highly examination-oriented curriculum for some of the difficulties encountered in exploiting ICT to best advantage (FI03, p3-4).

In identifying the drivers of adoption of ICT, the schools also pointed out some of the barriers to its use. An obvious obstacle for some was limited access to the equipment, as reported by a teacher in a Finland case school (FI02, p4). Others complained of lack of suitable educational software as a barrier to use: as put by one Greek principal, "You can find a CD with equations in general, but it is not close to the student's book…. Some others seem to be copies of the student's book" (GR05, p5). In a Finland example, teachers reported that "lack of pedagogically meaningful digital teaching and learning material" made integration of ICT more difficult (FI03, p3), and one teacher who experimented with ICT felt for this reason that the time spent could have been better used in conventional teaching (FI02, p4).

Many schools pointed out that using ICT properly involves considerable additional preparatory work by teachers, certainly initially (e.g. GR04, p7). In some schools teachers were given time to develop ICT activities (e.g. NL03, Jacobus); where this did not occur, lack of time was often reported as a barrier. In Finland, teachers complained that they did not have enough time to enrich their teaching with the use of technology (FI03, p4) and gave this as the main reason why teachers did not use ICT (ibid, p7).

Diffusion patterns

Rogers's classical model of adoption of innovations (1995) suggests that they are first adopted by small numbers of adventurous pioneers, and taken up by the majority only when the value of the innovation becomes apparent. This model may be applied to schools at two levels. At the macro level, individual schools may adopt ICT at different times. These case study schools were among the pioneers in their own countries, and so provide the models that may inspire others to adopt ICT. At the micro level within each school, teachers adopt ICT at different times. In most of the case study schools, ICT use spread gradually through the teaching staff but not followed this pattern. In a small number of cases all staff switched into using ICT, apparently simultaneously, and one of these was in Greece (GR01). This school had been recently built as a high-intensity ICT site, with selection of staff in part according to their technological abilities or willingness to engage in intensive relevant training, and the teachers had little alternative but to accept ICT in their teaching.

Some schools following the gradual pattern of adoption eventually reached the point where all teachers were using ICT. In a small primary school in the Netherlands (NL01, De Verrekijker), 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 training in their pedagogical uses. 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. Even so, some teachers were more reluctant to use technology than others and even after all had earned their European Computer Driving Licence (ECDL), some still reported technical problems using ICT in their teaching.

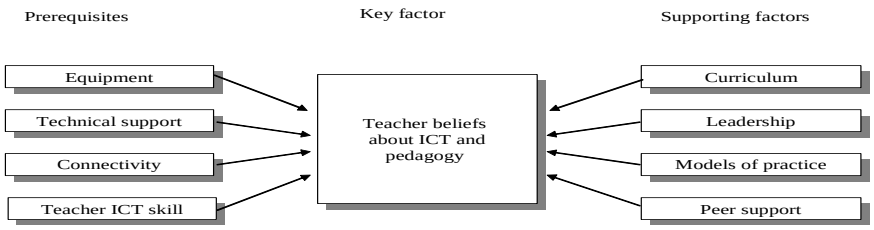
For most of the case study schools, however, there remained a small number of teachers who chose to be non-users. Occasionally these were openly sceptical of the value of ICT (FI03, Kupittaa), but more frequently they were simply not engaged in the process. In most cases these teachers were not pressured to use ICT, but arrangements were made to allow them to avoid it.

The predominance of this gradual pattern of adoption even within these innovative schools underlines the importance of teacher belief in the value of the process. So long as teachers can make an individual personal choice about whether or not to adopt ICT, their understanding of the role and the potential benefits of the technology is critical to its greater use. A key element in winning over teachers may be the presence of success models within the school; a number of the case study schools found that once a small number of teachers were successful with ICT, the majority began to support it. In Park Garden primary school in Canada, the innovation began with a couple of knowledgeable people who gradually trained others. Once the programme had become established it gained widespread support within the school, and when extra staffing became available, the staff consensus was that it would go to the computer lab (CA03, p6-7).

Lessons for the development of ICT in schools

Asking what can be done to encourage the use of ICT in schools invites the prior question of what kind of use is envisaged since it can take different forms. Its application in school administration or its use to teach operational ICT skills may be relatively straightforward and call for appropriate infrastructure and training. Where ICT is part of an educational reform, the issues of adoption are more complex such as where it is part of a move towards more student-centred styles of learning, often involving students completing projects or doing research.

FIGURE 2: FACTORS IN THE ADOPTION OF ICT AS EDUCATIONAL INNOVATION.



Certain factors can be regarded as prerequisites – their absence represent barriers to ICT adoption but their presence is not sufficient to guarantee its use. These include access to adequate equipment, reliable and fast connectivity, and adequate technical support to ensure reliable equipment. Teacher ICT skills may also be regarded as prerequisites: the case study schools reported many examples where fear of technology and lack of technical skill were barriers to use, but so were there many examples where teachers with ICT skills were not using them in their teaching.

The case studies point to the central role of the teacher's pedagogical beliefs and practices in the adoption of ICT. Teachers were largely free to adopt or reject ICT and to decide on its use, even in schools where it was heavily used. The gap between the acquisition of ICT skills and their deployment in teaching, reported in a number of schools, underlines the importance of teacher pedagogical skills for using ICT effectively. The cases identified a number of factors that may influence change in pedagogical practices. Curricula emphasising problem-solving and autonomous learning skills are more likely to encourage ICT's educational use than those focused on teaching and testing narrowly-defined bodies of knowledge, and in some cases, innovation with ICT began in response to changes in curriculum or guidelines. A number of the schools pointed to leadership as a key change agent, in building support for ICT adoption and creating an innovative environment where innovation was encouraged. Teachers' beliefs about ICT were influenced by the example of colleagues who were making use of ICT. This was particularly important where the existing uses of ICT were seen to be of educational value, and where there were deliberate strategies to share the experiences and support new teachers in joining the innovation.

6. Equity Issues

A widespread concern about ICT in schools is that it might advantage one particular group over others. Three equity dimensions are examined here:

- The first is the possibility that those students from less wealthy backgrounds are less likely to have access to a computer at home, and therefore be at a disadvantage when ICT is deployed in teaching.
- Second is the possibility that ICT may attract boys more than girls, providing additional motivational benefits to boys.
- Third, there is the possibility that ICT may have a particular benefit for either stronger or weaker students, thus potentially widening or narrowing the existing performance gap. The case studies were also sensitive to the use of ICT for students with special needs.

Each of the case study schools was asked to report its experiences of these potential differences. Most of the schools collected little objective evidence and so much of what follows is based on teacher opinions.

Home access

Many of the schools expressed concern that students without access to a home computer would be at a disadvantage. At Park Garden primary school in Canada (CA03), p8), all students are provided with equal access to ICT during school time. Despite this, the staff believed that the gap would widen between the more and less advantaged students, arguing that students with home computers can pick up the material more quickly and those with no place to practice their ICT skills will see their performance suffer. The school attempts to address this with after-hours computer clubs but does not regard it as equivalent to having a computer at home. In the Luxembourg schools, there was general agreement that students with home computers were at a clear advantage, especially when the parents encouraged their children to use them for educational purposes. However the teachers also noted that many students used the home computers only for game playing. (LU02, p12-13).

In a Korean case, (KO01, Banghwa), the students with home computers were not just getting more access, but were also using the technology in different ways. They tended to use the computers more for information access and learning than those without home access, who favoured on-line games and Internet chatting. Parents too can see the benefits of access. One Mexican school (MX02, p4) reported parents seeking access outside of school hours. As a parent put is, "why is there no access in the afternoon? There should be a small workshop for the students…as we cannot afford to buy them a computer at home". In some examples, concerns about unequal home access led to a reluctance to assign homework that required students to access computing outside of the school.

Not all agreed. Some argued that the differences resulting from variation in home access were insignificant. A school reported in Mexico reported that students without a home computer showed more interest in ICT and quickly caught up (MX02, p8). Some in other schools thought that the presence of computers in the school helped to narrow the digital divide by providing access for students from disadvantaged backgrounds. As the principal of a primary school in Canada explained "This is a community where income levels are not very high and access to technology is very limited… The kids tend not to have access to technology or other life experiences. … So if it happened at the school, the kids would get it. If it didn't happen at the school they would not get it anywhere" (CA04, p7). Teachers in another Canadian school maintained that computers were a strong motivating power in helping inner-city students to learn and succeed. As one described it "the lower kids who are hesitant to write in their journals jump at writing on the computer. They're not scared. Computers are really motivating" (CA03, p8).

A number of the schools had strategies in place to provide additional access to ICT for students without the benefit of home access. At Banghwa, Korea, (KO01), students had access to an after-school ICT laboratory. In Aurora school (FI01) students were also provided with access to ICT outside of school hours in a deliberate effort to ensure that those without ICT at home are not at a disadvantage. Similarly at Oost (NL04) students who do not have computers at home (some for religious reasons) can use the computers in the Information Centre at the school. Other schools provided support to allow students to have a computer at home. In Canada, Golden School (CA01, p8) put in place a series of measures aimed at compensating for lack of home access to computers, including making laptops available for loan for periods of 2-3 weeks and desktop computers on loan for an entire semester. In Italy (IT04, Tosi) and the UK (UK03, Littlejohn), as in several other places, laptop computers were available for students to use at home. In one school in Singapore (SG02), where first-year students were required to purchase laptops, financial assistance was available for those who needed it.

Some of the schools were also providing services to the community, as part of a wider strategy to bridge the digital divide. In Japan, parents of Gifu students (JP04) are offered seminars once each

month on ICT skills. In Canada, Lake View School (CA06) acts as a community Internet service provider and also provides technical support for the community as well as its feeder schools.

Gender differences

That ICT may attract boys more than girls has long been noted, and this was picked up in many of the case study schools. Oulu school in Finland (FI02) felt that ICT had a particular motivational effect on boys. Teachers in Lansimaki school (FI04) noticed that girls sometimes chose to avoid ICT activities. Recognising that this could lead to a damaging imbalance of skills, the school reorganised the curriculum so that all students were required to engage in some ICT activities (FI04, p10). An Irish school, St Sheila's (IE02) had the same experience. In the early stages of the use of ICT the students who had chosen to get involved were mainly boys. However, as ICT was "mainstreamed" all students were involved, and this seems to have been particularly beneficial for girls.

A number of schools recognised a gender gap, but saw the provision of ICT access in school as the solution. One teacher in Golden School, Canada said ICT "is a real equaliser… I think it has given access to boys and girls equally, and the skills that allow them to do successful things on the computer aren't gender specific" (CA01, p8). However, ensuring that boys and girls make equal use of ICT in school may not remove the imbalance. In Oulu school (FI02, p5), the teachers noticed that although there were only minor gender differences in the classroom use of ICT, the boys remained much more likely to use the computers provided for access outside of class time (FI02, p5). Boys may also be more likely to have a home computer. A survey in a Danish boarding school (DK02, Korinth) found that 22 of 26 boys had computers in their rooms, but only 1 of 23 girls did. A survey in Nic Bevier School Luxembourg also showed that 71% of girls and 82% of boys had a home computer (LU02, p14).

Not all schools found a gender gap – cases from Greece (GR04) and the Netherlands (NL01, De Verrekijker, and NL02, Marke) reported that no differences were found for learning with ICT. Others felt that the gender gap was narrowing: in Kupittaa School, for example, a teacher remarked on growing interest in ICT by girls (FI03, p4).

Gender difference in type of use

The gender differences may not be confined to the amount of use of ICT but to the type of use of ICT. The case study schools found examples of boys and girls using the technology differently. In general, boys were found to be more willing to explore the technology. Girls were reported to be more inhibited in relation to ICT use. The technical administrator in Bavaria school (DE02) described this difference as, "The boys first press all the keys, the girls first ask what could happen *if* they press a key." In Westwinds College, the tutors noted that male students seemed to be drawn to the exploratory possibilities of ICT, while the female students were more pragmatic (CA11, p14).

Other schools noted that girls concentrated more on the communication potential of ICT, while the boys were more interested in games and the web. Schools in Austria (AT03, Hall), Korea (KO02, Kyungin) and Finland (FI01, Aurora) 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.

These differences may work to the advantage of girls, in helping them to complete educational tasks. In a German school (DE01, Bonn-Beuel) teachers found that girls worked more purposefully with ICT. In the Netherlands (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. The tendency for boys to explore more of the technology's potential may, however, result in acquisition of better technical skills. In Lansimaki Secondary School in Finland, a survey revealed substantial differences between the ICT skills of boys and girls. Self-evaluation reports suggested that boys knew a range of packages well, but that girls were comfortable only with the Internet (FI04, p8).

High and low ability

The third equity dimension concerns the impact of ICT on students with different levels of educational attainment. Earlier studies (Hativa, 1988; Hativa & Becker, 1994) showed that with CAI as the primary classroom instruction for middle school mathematics, the gap between high and low aptitude mathematics students widened considerably. And indeed some of the case study schools felt that the benefits of working with ICT would be of greatest help to the most able students. A few suggested that the "better, more skilful, and advantaged" always learned more (FR01, Marie Curie).

One of the reasons given for this view was that weaker students might get bogged down in technical problems. Some Luxembourg teachers, for example, felt that the stronger students seemed better able to handle technical problems and so got more benefit from ICT (LU02, p13). The more able students may also gain more from ICT because of the open-ended potential of ICT tasks. In Oulu school in Finland students who had participated in an enquiry-based project had "clearly gained more problem solving skills and reached deeper understanding of the subject than the other students…"(FI02, p11). However, teachers interviewed pointed out that students with learning difficulties showed the same difficulties in ICT-based lessons. The high-achieving students often seemed to make better use of ICT, perhaps because it allowed more individual activities. In Lansimaki School, teachers pointed out that use of the Internet did not always encourage higher-order learning in students with low meta-cognitive skills. Their "project work" was often "copy and paste" which may have been a result of superficial learning processes (FI04, p16).

No easy solutions were proposed. In Oulu (FI02) teachers thought the answer might lie in more collaborative work to help the weaker students to learn from the others. But in Lansimaki (FI04), where students routinely worked in pairs, the teachers were worried that the weaker students tended to become passive followers.

ICT and lower achieving students

While most of the case study schools agreed that ICT use was beneficial for the most able learners, not all agreed that this would widen the gap between the most and least able. Some schools argued that there were also a particular series of benefits for the weaker learners. The potential benefits for the lower achievers may lie in motivation, self-esteem, independence in learning, or a perception that computers are fun.

One of the schools that saw ICT as having benefits at both ends of the ability spectrum was Kupittaa school in Finland (FI03, p4). Some teachers felt that students with higher academic skills might learn more effectively and adopt ICT skills better but ICT might motivate the weaker students more (Kupittaa, FI03, p4). At Westwinds College, Canada (CA11, p14), the teachers also argued that open learning has allowed them to attract students at both ends of the academic spectrum. Advanced learners are attracted because they want to "fast-track" and work at their own pace. At the other end of the spectrum, students who find trouble with the traditional classroom may be drawn to ICT because they see it as easier or more entertaining (CA11, p14).

A number of other schools noted ICT-related benefits for weaker students. In a Norwegian school (NO03, Bokn) it was noted that ICT gave weaker students an opportunity to experience success while in Israel (IL03, Neot, David), gains in self-esteem and motivation were reported. Several other reports highlighted gains in motivation, including St Luke's (IE06), Cabreiros (PT04), Littlejohn (UK03) and Highgrove (UK02), and in students taking responsibility for their own learning (e.g., NL03, Jacobus; NL04, Oost).

Students with special needs

Some of the case study schools reported particular benefits of ICT for students with special needs. One way was through word processing software seen as improving the quality of written work. In Germany a comprehensive school had followed a deliberate policy of integration of children with special needs into mainstream classes, and reported the benefits of word processing in allowing the students with

special needs to write more effectively and to produce legible work (DE01, Bonn-Beuel). Kaerby School in Denmark (DK03) found that students with special needs found writing quicker and easier to plan when using a word processor: they were less restricted by considerations of neatness and handwriting, and were able to write more.

In other schools, ICT was used to facilitate communication and social contact between students with special needs and mainstream students. In Austria, a school reported that students with special needs were able to make friends easily in chat rooms, because "on the Web, the other person's nationality, race gender and appearance don't matter" (Teacher, AT03, Hall). In a Danish school, students with autism, who normally have difficulty in establishing social contact, were able to build social networks and have positive experiences of social interaction using email (DK03, Kaerby). Kaerby School (DK03) found other benefits of ICT specifically for students with autism. The systematic and logical nature of the technology was attractive to the students, who like predictability and definite boundaries. The students generally felt more comfortable working with the computer; as one teacher put it, "It feels fairly safe to sit and work with this thing instead of confronting a person, which may be a little more unpredictable" (Teacher DK03). In addition to word processing and email, the school used computer games to bring the students with autism together with other children for common activities.

In sum: ICT and equity in the case study schools

No single pattern emerged on each of the equity dimensions discussed in this section. On differences in home access to ICT, clear variations were reported but teachers were divided on whether or not this made a significant difference. More suggested that greater opportunities to develop familiarity with the technology at home and to refine project work made a difference than suggested that this had negligible impact. It depends in part on the use made of the technology, while the perception of uneven home access may deter teachers from assigning tasks that might benefit the home user. A number of the schools had compensatory measures in place to help support those without home access, ranging from access to school computers after hours to schemes to lend computers or finance home computers for those in need. Such measures could well prove valuable in ensuring equitable access to ICT but they may also have significant cost implications.

While most of the case study schools sought to ensure that boys and girls get equal exposure to ICT, there were reported differences in motivation, access outside compulsory activities and in home ownership. Some suggested that the gap was declining and that there was little difference between boys and girls inside the classroom when they work on a common task. Boys in general were reported to be more interested in the technology *per se* and in games. Girls were often seen as more pragmatic users, seeing its benefits to achieve a particular aim, and as more attracted by ICT's communication potential. Attention to these differences may help to optimise ICT use for learning for both boys and girls.

The picture regarding the impact of ICT on students of different attainment levels is also mixed. Many of the schools noticed no difference, admittedly judgements backed by limited objective evidence. Again, impact is likely to depend on the type of use. Situations where students are expected to take a good deal of responsibility for their own learning - as with unguided web search - may well favour those with strong motivation and meta-cognitive skills. On the other hand, the mere presence of ICT is motivating for some students, and particularly for those without access at home. The improved quality of presentation with ICT, the ability to find new material, and the possibility for self-paced work may all contribute to increased motivation and self-esteem for weaker learners. The adaptability of ICT may thus allow it to offer worthwhile learning experiences to students at different levels, which may be especially valuable for differentiated learning in mixed-ability classrooms. ICT may also enhance the room to draw some disaffected young people back to learning.

Finally, ICT was also reported to have particular benefits for students with special needs. It can help students with writing difficulties, with resulting improvements in confidence and achievement, and it may enhance the opportunities for those with communication difficulties to relate to others, through email and chat rooms.

7. Academic Quality

The use of ICT in schools raises questions of academic quality. On the one hand, the technology offers the opportunity for more self-paced study, for learners to manipulate and re-draft their work to achieve higher quality, and for them to access a vast range of resources and to engage in simulations or constructive tasks that promote higher-order thinking. On the other hand, critics point to the amount of school time that can end up being spent on mundane operational skills, and the possibility that material can be replicated electronically without involving any learning. This question goes to the heart of the thinking about ICT in schools, and its value.

The case study schools were asked to consider impact of ICT on the quality of learning in their schools. One of the obvious outcomes of ICT innovation was improved ICT skills: in Park Garden School, a district consultant described the grade 6 class as "very advanced users" (CA03, p8). But, the benefits reported went beyond learning about ICT as, for instance, a number of schools reported gains in student motivation. In Luxembourg, ICT was seen as attractive because of its relevance. As the school reported: "ICT represents for youth something which is indispensable to their futures" (LU02, p11).

In some cases the technology project had changed the public perception of the school. This is clearly illustrated by the case of Park Garden School in Canada (CA03). Before the innovation, the school was known as a "rough school", and was sometimes called "Park Garbage". Now the name has become a badge of pride. Respect by students for school property has increased. In addition to ICT skills, students take with them a "generalised sense of pride and accomplishment, a feeling that they can do what pupils from more privileged backgrounds can do". There has been an increase in pupils' self-esteem. Grade 6 students scored well on responses to attitudinal statements "I like to write" and "I am a good writer". Much the same happened in Santa Maria Tlahitoltepec High School in Mexico. The reform associated with the introduction of ICT was seen as having raised school standards and as a result the demand for entry had increased (MX03, p7). In Iqnacio Quiroz Primary school too, one of the indicators of the impact of ICT was that the school became over-subscribed and had to turn away hundreds of pupils each year (MX04, p2).

A number of schools reported increased academic performance. One middle school in Mexico saw student standards rise following the use of graphing calculators (MX02, p8). A Canadian teacher reported deeper engagement than expected in an online discussion exercise, saying "I had some really good experiences with an on-line course… I had 15 or 20 grade 9 kids on-line, engaged in a conversation that was intellectually of a quality that I would expect a grade 12 class to engage in, because they were focussed…" (CA01, p9). Much of the learning was not attributed to ICT *per se*, but to the active learning methodology that was facilitated by its use as reported by the researchers for the Finnish study, ("it seemed that active learning with ICT facilitated deeper understanding of the problems students were dealing with." [FI02, p9]). In Australia, Bendigo School (AU01) had data on examination performance to suggest that students had benefited from the introduction of ICT. Over the four years that ICT had been used to promote a constructivist learning environment, the average grades of students had grown further ahead of the state average. Their advantage over the average was only 1.2 marks in 1996 (29.8 compared with 28.6), but while the state mean remained the same in 1999, the Bendigo score had risen to 31.1, having increased consistently in the intervening two years.

Not all of the schools were convinced of the benefits of ICT. Concerns were voiced in one of the German schools that teaching ICT skills in content-area lessons took time from regular subject matter and therefore resulted in less content covered (DE00). Teachers in Aurora primary school in Finland thought that the quality of presentation of student work had increased through use of ICT, but were unsure if the quality of the content had improved (FI01, p14-15). In Westwinds College, there were some teachers who did not believe that ICT was helping to raise standards for all learners. One teacher

felt that some students were inappropriately drawn to ICT and were "waiting for someone else to do the thinking". Another felt that ICT created "the illusion of being easy" (CA11, p17).

It seems likely that where benefits were found, they were not inherent to the technology but were related to the way it was used. A Portuguese secondary school stressed that the educational value depended on the learning situations promoted by the teachers, and not on the materials themselves (PT02, p12). In Ireland, teachers at St Sheila's school had experience of using a range of software. Their experience suggested that the effective use of drill-and-practice software was relatively unproblematic, but that effective use of the more open software was heavily dependent on teacher expertise (IE02).

The challenge of the Web

The World Wide Web provides a resource of enormous potential to schools. Students can use it to access up-to-date materials in a timely way compared with textbooks, of far greater variety than to be found in any school library. Expeditions, experiments and archaeological digs can be followed in real time, for instance. Opposing perspectives on current events can be compared, and massive archives searched. These vast resources can be a powerful tool in facilitating a pedagogy based on student research.

Access to the web, however, also provides particular challenges for educational quality. One of the issues is the loss of control over the instructional content. In a traditional school system, instructional materials are reviewed at different levels by administrators and teachers before reaching students. Within the school, libraries contain only material seen as suitable. Materials on the web are much more difficult to monitor or control. The risk is not simply that of pornography: the web can provide access to hate literature, incoherent material and inaccurate descriptions, which students may find difficult to recognise and assess.

A second quality issue relates to the pedagogy employed in educational sites on the web. Many rely on a drill-and-practice methodology, with a minority including more challenging tasks. One study of 500 educational sites found that only 5% included problem-solving or decision-making (Mioduser & Nachmias, 1999). In contrast, 42% of the sites featured rote learning and just over half were mainly about information retrieval.

A third difficulty for teachers is the need to locate suitable materials for different age levels and areas of interest. Students searching the web may uncover large volumes of material that is relevant and correct but inappropriate because it is aimed at a level well above or below their needs. Indexing systems to overcome this difficulty are in their infancy. Without the skills to make good judgements about the material they find, students can waste considerable amounts of time. Once they have located the material, ease of copying through cut-and-paste operations presents a temptation to capture the information without processing it.

School responses

The case study schools had taken some steps to deal with these quality issues. In some cases, this involves controlling what students can view on the web. In the two Australian schools, "Staff members critically evaluate technical resources as they would other resources" (AU00, Summary). In Israel (IL03, Neot David), students are under "strict supervision" while on the Web. In the Netherlands (NL01), access to the web is through a national educational network, Kennisnet, which restricts access to unsuitable material.

In other cases, the educational use of the Internet was curtailed because the teachers were not convinced that they could find exactly what they needed. Two Finnish schools (FI01 and FI02) said that teachers avoid being dependent on electronic learning materials, and instead see ICT as primarily a resource for the students. Teachers in one school in Ireland (IE03 Peadar and Pol), "..have chosen not to integrate the Internet into their lessons as they fear it will have a negative effect on academic standards."

"Easier access to information does not necessarily mean that the students keep it or process it" (DE00, Summary). One school in Luxembourg reported that a large number of students were lost when faced with the vast amount of information on the web. As a result a lot of random pages were printed from the web. Teachers felt that students had difficulty in distinguishing useful information, but the students themselves did not recognise the problem (LU02, p11). Some voiced a concern that the quality of learning was reduced due to excessive time seeking information rather than analysing it. This might be a particular problem for weaker students, suggested one Korean case (KO02, Kyungin), as the time involved in information-seeking gives rise to frustration.

Some schools responded to these issues by deliberately teaching students the skills of identifying and assessing relevant information. In Golden High School in Canada, some teachers see the use of the web as a factor in increasing standards. As one put it, "I feel like students today are drowning in information and starving for knowledge. And we make all this information available to them but they don't know what it is and how to deal with it. They can't discriminate… We have to recognise that as educators, and give them the tools to make critical judgements… critical thinking is the most important part of what I teach." (CA01, p9). Also in Canada, in Spencer school, the students were taught critical thinking skills. Once these skills were developed, the school believed that the variance in quality of materials on the web were not as critical an issue (CA04, p7).

The difficulties presented by the variety of material available on the web may be particularly significant where the teachers do not have the skills, confidence or subject mastery to select the most appropriate content. One report from Korea (KO02, Kyungin) described teachers who were overly dependent on ready made Web materials. In Hungary (HU04), it was noted that novice and less qualified teachers were most limited by low quality materials on the web. These teachers were usually the ones most dependent upon textbooks and other instructional materials and had the least ability to adapt materials to meet specific educational objectives.

ICT and academic standards

The case studies thus present a mixed view of the impact of ICT on academic standards. On the positive side, schools reported that ICT was motivational, and had a particular symbolic value in some disadvantaged communities. Some schools reported increases in academic standards, and a few had even collected data to support this claim. However, most of the change in standards was attributed to the method being used, generally involving more emphasis on student-centred tasks, than to the technology itself.

A similarly mixed view of the web was reported. While few doubted the enormous potential offered by the web, practical difficulties sometimes limited its value. Besides the risk of children encountering undesirable and potentially harmful material, vast amounts of time could be wasted in unsystematic searches. Some web-based educational sites were found to be of poor quality with rote learning far outweighing inquiry as the main pedagogical approach. Schools were aware of the potential threat to academic quality arising from ICT use and had adopted a variety of solutions to counter this: some schools deliberately restricted web access, or tried to guide students towards useful sites, while others sought to teach students the skills to evaluate the material they found.

The experience of these schools does not suggest that any particular technology results in an increase or decrease in educational standards: all of the technologies have the potential to waste a good deal of students' time and they can all provide opportunities for more engaging and challenging educational experiences. The crucial variable seems not to be the medium but the method employed. Where the technology was used as part of a clear pedagogic strategy, it more frequently resulted in positive outcomes.

The web poses further challenges. Its worthwhile use often involved a deliberate attempt to teach the skills of critical evaluation and application of the material found in searches. These skills can be described as "critical literacy" - the ability to discern the value and relevance of material discovered out of context and then to build a meaningful synthesis from it. While critical literacy may not be highly valued in some curricula, it is likely to become increasingly important as society becomes ever

more information-rich.

8. Concluding Summary

The stories emerging from these case study schools provide insights into the issues surrounding ICT as an innovation. The case study schools, spread through 22 countries, cannot be presumed to be representative of all schools, but they are illustrative of the patterns of use and the emerging concerns in schools innovative with ICT. Each section of this chapter has presented a concluding summary that need not be repeated here. By way of closure, two recurrent themes can be usefully underlined. First, the teacher is central in the adoption and use of ICT. The impact of ICT on educational quality, on learning, and the differential benefits from these all flow from the way in which the technology is used. The same technology, in the hands of different teachers, produces different outcomes. Second, the adoption of ICT is not a technical implementation but an ongoing process of educational change. It is about teacher beliefs and pedagogical practices as much as about infrastructure and bandwidth. As such, it may be a slow, often unpredictable process.

ICT as an innovation

One of the interesting patterns was the diversity of uses of the technology: schools used it to support movement towards a variety of educational goals. These can be classified into:

- ICT as the focus of the innovation (ICT skills)
- Teaching and learning with ICT
- Educational management with ICT
- Extending the boundaries of the school.

These groups were not mutually exclusive, and many of the schools had used ICT to make progress towards more than one of these aims.

Where schools used ICT in support of teaching and learning, this often involved facilitating more student-centred learning, on a modest or a more ambitious basis. Despite differences in scale, these innovations were similar in involving students taking greater responsibility for their own learning and finding answers for themselves. This frequently relied on the use of "open" or content-free software, such as standard office word-processors, presentation packages and spreadsheets. There was relatively little use of specialist educational software, and where educational software was used, it was often associated with repetitive drill activities rather than with project work.

Although the Internet may seem the obvious tool to facilitate the development of research work by students, it was not used as much as might be expected by the case study schools. The quality of connectivity was certainly a barrier in many schools, to the point of deliberately orienting students away from the web because of difficulties with the speed and reliability of the connection. However, this may be a less significant barrier today, as the quality of connectivity has improved considerably since the case studies were conducted around 2000.

The other barriers to use of the Internet were concerns about the quality and relevance of the material. Some schools were concerned with the risk of students accessing unsuitable material, such as pornography, while in others that the volume of irrelevant material, or material pitched at the wrong level, might disrupt the students' learning. The web is too vast and unstructured to be used without preparation work. Teachers might guide and structure searches more effectively or students could be taught better skills of analysis and discrimination.

These patterns of use suggest the following general conclusions:

- First, ICT is a flexible technology that can be used to support a variety of educational aims. In the absence of clear policies, schools adopting ICT may not all move in the same direction and policy may need to provide supports to encourage desirable school ICT use.

- Second, ICT can facilitate student-centred approaches, and where this occurred it was tended to have led to significant reported benefits in motivation, understanding and, in some cases, performance in examinations. However beneficial progress on a small scale by individual teachers may be, a whole school approach is preferable. This may involve significant reorganisation of school schedules, working arrangements and staff roles. Innovation on this scale is more a process of educational change than one of technology adoption.

- Third, where schools use ICT to support student-centred approaches, this often requires little more than standard office software. The web offers potential as a research resource, but its utility was often limited by the quality of connectivity. Once connectivity issues are overcome, schools will be faced with the question of managing large volumes of inappropriate material. This may be seen as a barrier, or as an opportunity to teach important information-handling skills.

ICT as a catalyst for educational change

In the move towards an information society, the demands placed on education systems will change. Many have argued that there will be less need for formal education to transmit a fixed corpus of knowledge, and much more need for the development of meta-cognitive skills; the skills of evaluation, analysis, problem-solving and learning to learn. It is anticipated that schools will move towards a more student-centred model of learning, involving more project work, with students taking more responsibility for their own learning and developing the kind of autonomous practices that will enable them to grow as lifelong learners.

ICT is often seen as playing an integral part in this change, and it has been suggested that it may act as a catalyst or stimulus for the change; a central question of this study was whether ICT had a catalytic effect. The studies revealed a varied pattern. Sometimes, ICT was clearly driving change; more frequently, it was facilitating pedagogical change which was already planned by teachers or management. In a third group of schools, mainly focused on teaching ICT skills, ICT was not associated with a pedagogical change at all. Overall, it could not be said that the introduction of ICT automatically resulted in educational change.

Despite this, there were numerous cases where pedagogical change relied heavily on the technology. Where it did occur, this was usually associated with a strong belief in the methodology, by school leaders, by an ICT champion, or by innovative teachers. On this basis there were plenty of examples of ICT acting as a change agent - both by encouraging other teachers to get involved and by facilitating the practical application of the change. It is thus more realistic to characterise ICT as a lever, giving power to an existing movement, than as a catalyst or initiator of change.

The technology itself is value-neutral in this regard: it can be used to support strongly didactic traditional teaching or a student-centred model. But the technology implementation was not always value-neutral. Where school leadership consciously sought to encourage a shift in pedagogical practices, ICT was sometimes introduced to drive that change. In some schools, for example, teachers expressed surprise at the amount of educational discussion in ICT courses, and said that ICT had changed their teaching methods more than they had expected initially. In these cases, ICT was part of the process of educational change.

For policy, such conclusions imply first that ICT cannot be relied on to trigger educational change, calling in question reform strategies built mainly on ICT deployment: the important contribution it has

to make will be primarily as a facilitator of the change process and as a tool for implementation. Second, insofar as ICT has acts as a lever, this may be very time-specific. When it is being introduced in a school, the opportunity may open to draw staff into professional development, re-organise schedules, and review educational aims. Once the technology has become embedded, it may serve little as a lever. If so, the greatest impact may well be gained when development of an educational vision for ICT is timed to match the deployment of infrastructure.

Factors in the adoption of ICT

Regarding implementation, the major message from the studies is the central importance of teachers' beliefs. Those enthusiastic about ICT succeeded in using it despite inadequate infrastructure and institutional supports. The decidedly unconvinced were able to avoid using it even in schools making a determined drive to encourage ICT use. Appropriate teacher development is thus critical, but many of the schools noted dissatisfaction with what was provided. It was most valued when it was seen as relevant and applicable in the classroom, while training centred on giving teachers technical skills, while useful, did not necessarily lead to greater use in teaching; in many schools, teachers with ICT skills well out-numbered those actually them in the classroom.

The case studies highlighted infrastructure issues that were barriers to ICT use. Access to equipment was a problem, even in schools not short of equipment itself. Equipment was often reserved for particular uses, or scheduled in such a way to make access problematic. The reliability of the equipment often presented problems. Few schools were happy with the level of technical support and the disruption caused by technical difficulties was seen as a major impediment to ICT use. Connectivity was, at the time of the fieldwork at least, also problematic in many schools.

Infrastructural issues are only part of the picture. The culture and attitudes of the organisation play an important role in educational change with ICT, with particular importance also ascribed to individuals and groups within the school - the principal, the ICT specialist, and colleagues. These provided support in specific tangible ways but perhaps more importantly they can be pivotal in shaping a culture of innovation in which teachers can safely develop their use of ICT. Some schools saw their competition with others in the neighbouring area as a driver of change, with the success of the innovation measured by enrolment increase. This is likely to be based on parental perceptions, rather than objective measures, and highlights this source of influence on ICT use in schools.

These patterns have implications for policy. Professional development needs to address especially pedagogy and attitudes, rather than simply on technical skills - changing attitudes may well be a long process for many teachers. It is tempting to view ICT as a single innovation, to be adopted once and for all. The cases studies here suggest that the process of change is the source of the creative educational thinking; sustaining creative educational practices will often call for a continuous cycle of innovation.

ICT and equity

The schools in the case studies reported a small, apparently declining, gender gap. In some cases boys had more access to ICT, and higher skills and more interest in this regard. There was little to suggest that girls were disadvantaged educationally by this, and in most cases boys and girls were reported to make equal use of ICT for school work. Care may well be needed to ensure that the gender gap is indeed declining, though the interest among boys should be capitalised on in attracting them to education more generally.

A second equity dimension was home access to ICT, given familiar patterns related to family income. Once meaningful educational activities using the computer are established in the school, there is the potential for students with home access to gain an advantage. Recognising the potential equity problem, many of the case study schools had schemes to facilitate access - some provided laptop computers on loan or even desktop computers on long-term loan; in others, the issue was addressed by extending access to the computers after normal school hours. Such measures help address the "digital divide" but they can also add to the burden of costs for schools.

Schools were also asked to examine whether ICT benefited the most or least able students. ICT was generally seen as motivational and so attracted students who might otherwise not have been so engaged and indeed have left school. The prestige of participation in an ICT project can mobilise community interest in ICT and the school, and the ability of students to manage their own learning with meaningful tasks through ICT is also motivational. Such benefits could be of particular significance for the most able learners and for the weakest. For the former, the open-ended nature of project work allows them to achieve more and remain challenged; for the least able, the project focus allows them to achieve satisfying results at their own pace. Such benefits are associated, however, with project-based learning, rather than with the technology of itself.

Particular benefits were reported for students with special needs: those with autism were particularly attracted to the technology and enabled to communicate via online forums and chat rooms.

ICT and educational quality

The case studies provided examples, largely based on teacher opinion, of the potential of ICT to enhance educational quality; they also identified teachers with concerns about it leading to waste of student time and the encouragement of superficial work. The mix of responses was especially marked as regards the web: some saw it as a valued resource for student research, others as encouraging a "cut and paste" culture. This range of opinion reinforces that the educational impact of ICT depends largely on the use to which it is put. Given the diversity of uses, ICT cannot have a single educational outcome. The question of impact begs further questions of what is valued in education. Where ICT is used to facilitate a student-centred approach, it is likely that this will promote *inter alia* the development of analytical and information handling skills. While they are important life skills, they may not be reflected in curriculum and assessment systems; student-centred learning will tend to flourish on more fertile ground when there is harmony with such assessment systems.

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