

SCHOOLING FOR TOMORROW

Learning to Change: ICT in Schools

EDUCATION AND SKILLS



CENTRE FOR EDUCATIONAL RESEARCH AND INNOVATION

Learning to Change: ICT in Schools



ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

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FOREWORD

The CERI project “Information and Communication Technology (ICT) and the Quality of Learning” was launched at an International Seminar at OECD in June 1998, with the participation of 25 Member countries. It was a direct response to the interest in this topic that OECD Education Ministers had developed over the previous two years (and which has since been re-iterated). Within the project, an area of work developed in relation to the use of ICT in schools, to consider what makes for quality in the ICT-based learning experience. The present book is the outcome of that work. It is to be seen as a companion volume to *Learning to Bridge the Digital Divide* (OECD, 2000), which arose from the same CERI project. The analysis of markets and partnerships in this project has also produced the publication *E-Learning – The Partnership Challenge* (OECD, 2001*b*). Further reports will be published in 2002 on the impact on ICT on innovative schools and on student learning.

A working group was selected to be representative of policy making, teaching, academia, and the software industry. Meetings involving most of the Members were held in April 1999 (OECD), October 1999 (The Hague), and May 2000 (Budapest). Papers were prepared by group members and others, to compare national experiences and to look initially at issues of software quality criteria and the purposes they served.¹ The emphasis was on cross-curricular principles rather than subject-specific issues. As the work developed, it became apparent

1. They can be found on <http://bert.eds.udel.edu/oecd/quality/papers/papersframe.html>.

that the concept of quality had to be understood more comprehensively. It was not simply properties intrinsic to the software materials themselves, but how those materials were used. Ultimately, this had to do with school organisation and leadership, the levels of resourcing, the quality of the teaching, the nature of the curriculum and patterns of student assessment.

At a second international seminar in February 2000 (Poitiers), a country questionnaire was discussed, designed to elicit information on: the effects of ICT on the school curriculum; teachers, headteachers and their professional development; software evaluation and development; and educational use of the Internet. Subsequently, 16 Member countries responded, and others provided related information. These responses (shown as country notes in the bibliography) formed a major resource for this present report. A further resource was provided by an international network of students organised by OECD, one from each Member country (with one exception). The students exchanged views electronically during 2000, and met at the end of the year in Aix-en-Provence.² They provide a refreshing and perceptive user-perspective. The concluding chapter of this report includes an address given to Education Ministers, meeting at OECD in April 2001, by Professor Seymour Papert, of the Media Laboratory, Massachusetts Institute of Technology, US.

Those who assisted the Secretariat in the working group are shown on the acknowledgements page, but some must be mentioned in particular. The student network was the inspiration of Pierre Duguet, who was largely responsible for managing it and reporting on it. Angela McFarlane made important critical contributions to the preparation of the report at various stages, drawing on her very considerable experience in this field. The initial drafting of several of the chapters in the report was undertaken by Aidan Mulkeen and Robin Ritzema. These four took part in a final revision meeting at the end of April 2001. Within the Secretariat, David Istance provided strategic and critical support throughout; the report was written and prepared by Edwyn James. The book is published on the responsibility of the Secretary-General of the OECD.

2. See “School Technology through the Eyes of its Users”, Report on the Aix-en-Provence Roundtable, <http://bert.eds.udel.edu/oecd/roundtables/roundtablesframe.html>.

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CHAPTER 1

POLICY PRIORITIES FOR ICT IN SCHOOLS

The ubiquitous presence and utility of ICT in modern life are having a significant impact on the way we live, and even on the notion of an educated person. It has led to the concept of the knowledge society – sometimes also called the learning society or information society. There is a widespread awareness that these developments have profound implications for education, and that schools must change, but as yet little detailed consideration of the extent of the change needed and the advantages that ICT can bring. The growth of the knowledge society and the pervasiveness of the technology represent a major challenge *and* a major opportunity for education.

All countries wish to enhance the quality and effectiveness of the learning process in schools, and are looking to ICT as the means whereby this may be achieved. Huge investments are now being made to equip schools with ICT. Governments want to know the conditions to be satisfied for this to lead to improvements in student attainment. In a fast-changing environment, they are often searching for the best way forward, and anxious to learn from the experience of others. This chapter considers the rationale for schools to adopt ICT, and goes on to discuss the notion of quality in the ICT-based learning environment. It concludes with a set of policy imperatives, for quality in learning to be secured. These recommendations are exemplified and fully supported in the chapters which follow.

WHY SCHOOLS HAVE TO ADOPT ICT

In at least three important respects, the dramatic changes in education implied or already brought about by ICT differ from any previous reform. First, earlier curriculum reforms arose *within* education, as educators attempted to put their own house in order. ICT has arisen *outside* the world of education, but with an irresistible case for adoption within schools. Secondly, and remarkably, it often happens that those who are taught are more comfortable with the new developments than their teachers. Finally, the pervasive nature of ICT has profound implications across the ethos and organisation of the whole of the learning environment.

We can distinguish three main rationales for the inclusion of ICT in education: the economic, the social and the pedagogical. There is some overlap between these approaches, but they can imply different emphases for the way that ICT is introduced and used in schools. For the *economic rationale* the focus is on the perceived needs of the economy – present and future – and the requirement in many areas of employment to have personnel with ICT skills. Knowledge of and familiarity with ICT is an important aspect of employability as the 21st century unfolds. There is a widespread expectation on the global scale that those nations successfully embracing the information age will benefit economically. Awareness of this economic dimension may encourage learners generally to acquire such skills, and some to take ICT as an additional optional subject leading to a vocational specialism, including the study of computer science in further or higher education.

The *social rationale* focuses on facility with ICT becoming a prerequisite for participation in society and the workplace. Competence with ICT is seen as an essential “life skill” in the same way as literacy and numeracy, so much so that the range of skills and processes supported by ICT is brought together in the notion of digital literacy, which becomes both a *requirement* and a *right* for all learners. It is therefore important to find ways to compensate those with limited access to computers outside school. Societies will suffer if some of their members have little or no facility with ICT, especially since public and other services are increasingly becoming available on-line. As usage of ICT becomes more extensive across society, wider benefits will also flow – better links between home and school, greater parental involvement in student progress, and greater scope for schools and other educational institutions to play an inter-active part in community life and development.

Thirdly, the *pedagogical rationale* concentrates on the role of ICT in teaching and learning. The potential for this has developed rapidly and dramatically with advances in ICT, from the early “drill-and-practice” programmes, and limited use in a small number of subjects. ICT can increase the breadth and richness of learning, not least through the topicality and realism that the new resources can bring. It can support the development of higher-order thinking skills, including analysis and synthesis. Students in the OECD international network found the pervasive use of ICT in schools to be motivating: they wanted schools to reflect – and provide a suitable preparation for – the realities that they recognised in contemporary life. Where this was not the case, they become increasingly disaffected with what school could offer.

There is a growing convergence between the economic, social and pedagogical rationales, since the digital literacy acquired and developed through the educational use of ICT is explicitly needed in the work and leisure of contemporary life. Between them these three rationales make a compelling case for education to take full advantage of the benefits offered by ICT. Modern society is increasingly looking to schools to foster independent and creative thinkers who can confidently solve problems and manage their own learning throughout their lives, the very qualities which ICT supremely is able to promote.

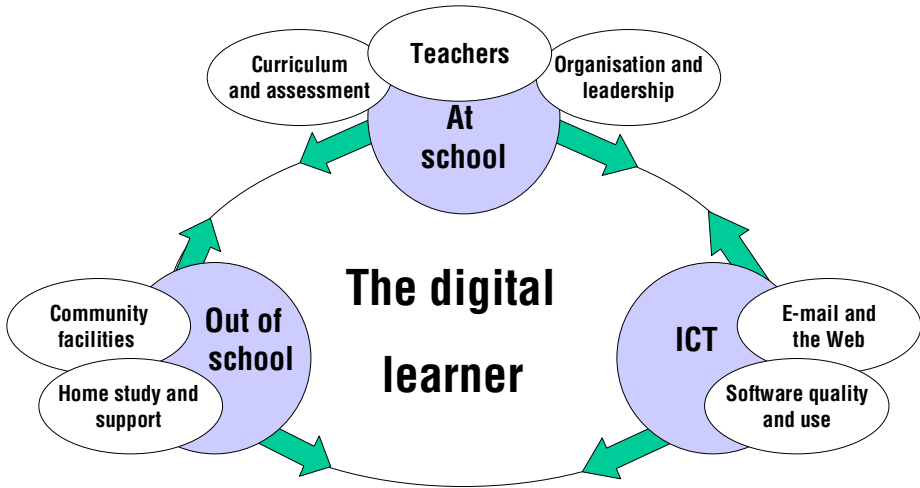
THE ISSUES TO BE ADDRESSED IN THIS REPORT

Once governments have decided to equip schools with ICT, interest moves towards establishing the conditions under which quality outcomes can be achieved. It is not a matter of simply using the technology, but of how it is used and for what purposes. The report draws on information from many OECD countries, and from the views of the students who formed an international OECD network to share personal experiences of their own use of ICT in school. It becomes apparent that many factors have to be considered in the search for enhanced quality in learning. What those factors are is the substance of the succeeding chapters of this report. They are introduced in summary form in the diagram below, which shows the major influences that impinge on the ICT-enriched learning environment of an individual school student, the *digital learner*.

The focus in the diagram is deliberately learner-centred, and takes account of the three major domains which together determine the totality of the learning experience of the student – life in school and life out of school, pervaded both by the resources and communication mechanisms of ICT. This is not to suppose that

learning is restricted to the use of ICT, but that powerful new links and opportunities are provided by this means. It is these that are considered in this report.

In spite of the expectations of some, that ICT would diminish the importance of the teacher, and even of the school, the reality appears otherwise. The school remains a central feature for the learner, and it is the teacher who remains the main point of contact. There is within school, however, a need for organisational changes and a different role for the teacher, through the integration of ICT.



How are dramatic changes on the necessary scale to be achieved? Some countries are making particular provision for school principals to receive professional development, since it is they who must determine the strategy for ICT to be successfully implemented. They are also making provision for technical and pedagogical support mechanisms by a variety of means. A novel possibility is to employ students who have technical expertise, on a part-time basis out-of-hours.

Many governments have recognised the need for pre-service and in-service professional development for teachers, to equip them with the technical skills for using ICT, and to know how to incorporate it effectively into their teaching. Increasingly, ICT is being introduced into initial teacher education, although having to compete for space with other priorities. The report illustrates several approaches for serving teachers, who more-and-more are using electronic networking to extend their professional competence. The well-networked teacher, engaged in such continuous professional exchange and development with

colleagues, will become for the student an exemplary role model of lifelong learning. Should time be found for such networking and other extensions to professional activity as a contractual right and obligation? How are the costs of providing adequate development and enhanced professionalism for teachers to be met?

There is a general trend towards adoption of ICT across all subjects, to enrich the learning environment. In the first instance ICT may simply provide an alternative delivery medium, as when an encyclopaedia is stored on CD-ROM, or writing is done using a word-processor. This offers some gains to the learner, but schools have also developed more novel ways of using ICT, as the report indicates, with illustrations from the experience of the students in the OECD network. Students are seen judging the relevance of an activity to the task in hand, assessing quality and reliability, working constructively in a team, and deploying materials in ways that add value and support the learning process.

How are schools to move to a greater emphasis on these new opportunities supported by ICT? Because such skills and processes are not customarily tested through orthodox examining methods, they appear under-valued in traditional curricular approaches. Is it not increasingly incongruous to limit student assessment to what can be measured by traditional hand-written examinations? Several countries are experimenting with ICT-based examining techniques; as ICT becomes a pervasive influence and working medium for teaching and learning in schools, then it should come to enjoy a corresponding importance in their assessment procedures. There is renewed interest also in formative assessment – regular informal updating of student progress and difficulties – since ICT offers promising avenues for rapid diagnostic feedback, to refine learning and teaching strategies.

Schools use a wide range of software and digital content, much of which was not specifically developed for education. Judgements of quality depend on the use to which the materials are put as well as the properties intrinsic to the materials themselves. Many evaluation schemes have moved from fixed standards to be met to application of open and flexible guidelines, in view of the growing number of materials and range of use. There is a critical role for teachers in the ICT evaluation process, and gaining such proficiency is an important aspect of professional development. Increasingly ICT-based materials used in teaching and learning will be partly commercially developed, partly produced by the teachers and learners themselves.

As an abundant source of information and means of communication, the Internet opens up unparalleled possibilities for learners and teachers. Given the

fluidity of Internet use, including learners generating content as they interact with each other, the focus for quality evaluation of Web-based resources shifts towards empowering students and teachers to make their own discriminating judgements. This shift is a marked departure from earlier forms of purportedly objective software evaluation, and leads to the concept of an “Internet learning style” – interactive, search-oriented, collaborative, but with individual autonomy. Educational portals select and classify educational materials to enable purposeful searching. It becomes impractical for them to offer independent evaluations, but some incorporate feedback from users and descriptions of actual classroom use, which adds to their value to teachers and students. How is such feedback to be stimulated on a larger scale?

This report illustrates that ICT has established a new complementarity between formal learning in school and informal learning outside. The critical relationships between home and school – that stimulate quality learning when they work well – become more important with the advent of ICT. Traditionally school work has been supplemented by homework, but homework that was very much seen as a reinforcement of formal school activity. Other learning that took place out of school attracted little attention within the formal curriculum and was largely discounted. ICT has added enormously to the possible strategies for learning *out* of school, in support and extension of learning *in* school, at a minimum when students can use CD-ROMs at home, but especially when there is ready home access to the Internet.

Out-of-hours, students access school Web sites and others of their own choosing, sometimes interactively. They learn by e-mail communication with their peers in a mutually stimulating and supportive fashion. Dialogue arises more easily and more meaningfully between schools and homes via Web pages and e-mail, promoting greater understanding between them, as the learner, the teacher and the parents establish an identity of purpose. What can be done to make effective partnerships between parents, students and teachers more normal? Some homes have little or no ICT resources, however, or cannot afford extended on-line activity. To what extent can low-cost public facilities with easy user-friendly access compensate in such cases?

These are the themes and concerns summarised in the diagram and dealt with more fully in the report. The diagram intentionally emphasises the interdependence among the different elements, since a vibrant and effective learning environment must simultaneously take account of each. It is the intention of the report to indicate how the adoption of ICT has the potential to enrich the

learning environment in hitherto unimaginable ways, and to establish the conditions under which these gains can be delivered. The main policy concerns identified below have been distilled from the various chapters. They are presented as a summary of important issues to be addressed, and problems to be resolved. Each is amplified and illustrated in the pages that follow. Quality in the ICT-enhanced learning environment requires attention to them all.

DIRECTIONS FOR POLICY

Radical curriculum change is needed in the Internet age

Powerful tensions exist between traditional curricula – based on well-defined content and rules for students to learn and be able to reproduce – and the open, skills-based, student-centred approaches supported by ICT. Dominant curricular and organisational patterns in school were not designed for the Internet age, and often inhibit its effective use. ICT offers some gains for traditional curriculum delivery, but its full educational potential cannot be realised without radical changes in school structures and methodologies. As ICT gains acceptance in schools, it may become both the driver and the facilitator of the necessary curriculum change.

Student assessment must be compatible with ICT-enriched learning

The promotion of advanced skills and competences will fall short in assessment regimes that are overwhelmingly based on achievement in single subjects, by means of conventional written examinations. What is assessed in schools and how the assessment is performed exercises a tenacious influence on the delivered curriculum. To continue with existing patterns of student assessment will act as a brake on the imaginative use of ICT. The pervasive adoption of ICT not only *requires* different assessment procedures but *provides* a variety of means.

Digital literacy is now a fundamental learning objective for all

Just as “conventional” literacy is more than basic ability to read a sequence of words, digital literacy is more than ability to use a computer in simple ways, and both are fundamentally important. It implies a sophisticated set of competences pervading workplace, community and social life, including information-handling skills, and the capacity to make judgements about relevance and reliability when searching on the Internet. Digital literacy is a vital part of the foundations for lifelong learning and must have a high priority within the curriculum.

Schools must be fully equipped and supported for using ICT

Effective use of the technology requires suitable levels of equipment, for use on demand within each classroom, and readily available to students out of lesson time. Internet access has increased dramatically, but more work stations and higher bandwidth are needed, to promote extended and sophisticated use. Exceptional grants for the initial installation of ICT have to be followed by regular funding for maintenance, technical support, and the cost of being on-line – that can be a severe deterrent to Internet use. An on-going re-equipment programme will be needed over time to sustain quality use.

Schools need plentiful educational software of quality and easily-accessed information on it

Teachers need a comprehensive supply of quality educational software to be readily available, with easily-accessed on-line information about it, concerning subject coverage, intellectual level and ease of use. It is particularly informative to include judgements by teachers on actual classroom use. Sustained dialogue is needed between ICT suppliers and the education service, including teachers, to improve the range of software and digital content. Often it will be for governments to promote such dialogue and share some of the risks of new development.

ICT in schools requires an extended professional role for teachers

Teachers face a more demanding professional role as managers of the ICT-enhanced learning environment. They must have a range of technical and pedagogical skills, with continuous up-dating to match advances in the technology and modes of use. Much will be achieved through electronic networking with colleagues in other schools, universities and elsewhere, ICT becoming both the object of professional growth and the medium through which it is achieved. Without adequate investment in teacher professional development and enhanced professional activities, effective technology integration into schools cannot succeed.

School leadership and management must be fully committed to adopting ICT

Visionary school leadership is needed to bring about and sustain the dramatic changes enabled by ICT, to persuade and give confidence to all involved – teachers and learners, parents and others in the school and community. The school must be re-organised so that working with ICT becomes integral and unexceptional, with a move away from the traditional individualistic and isolated modes of teaching, and emphasis on digital literacy for all. Schools are often resistant to

radical change, but ICT could be a “Trojan Horse” – the means through which change is delivered being also the way that resistance is overcome.

School, home and community have new opportunities for partnership

ICT encourages – and ultimately requires – a rapprochement between formal education and the learning that takes place outside school. It brings impressive channels of communication between students, teachers, parents and the wider community, that must be purposefully developed and actively sustained. The most effective learning environment is one based on a dynamic partnership between home and school, formal and informal, teacher and taught. This underscores the seriousness of the situation for students who have inadequate home facilities, who are on the wrong side of the “digital divide”.

CHAPTER 7

LOOKING TO THE FUTURE

The current three-year OECD programme “ICT and the Quality of Learning” was launched in 1998, as a major activity within the Centre for Educational Research and Innovation. It arose as a direct response to the interest declared by Ministers of Education in the Member countries. As the programme moves towards its conclusion, therefore, it is entirely fitting to find that the interest of ministers has been strongly maintained and reaffirmed.

A special forum on “ICT and Education” was held at OECD on 2 April 2001, alongside the regular five-yearly meeting of Education Ministers. There was an attendance of some 200, including ministers and senior officials. At the regular meeting (OECD, 2001*c*), the themes within this present report on quality issues were widely endorsed. It was recognised that investment in hardware and software needs to be complemented by investment in the skills of the educators, that teachers must be at the heart of reform, and that their professional development is key. As yet ICT is seen to have been under-exploited in promoting new approaches to improve the quality of teaching and learning.

The forum¹ itself provided lively support for the same themes and some useful supplementary information was supplied by ministers. It appears that all Korean teachers (and disadvantaged students) have been provided with a

1. See “ICT: School Innovation and the Quality of Learning – Progress and Pitfalls”, <http://www.oecd.org/cer/>.

computer, and other initiatives have been taken to combat the digital divide. In a partnership with industry, an Icelandic initiative has provided laptops for all secondary students; teachers are changing their methods and home learning is now seen to be crucial. There was recurring emphasis across the meeting on the need for measures to ensure the necessary professional development of teachers, in respect of pedagogy as well as technical skills.

The main input to the forum was a keynote address from Professor Seymour Papert, of the Media Laboratory, Massachusetts Institute of Technology, United States, who himself drew attention to the need for radical changes in education, if the full potential of ICT is to be exploited. He went on to emphasise the *constructional* aspects of learning as well as the *communication* that ICT facilitates. The text of his address is reproduced here in full. It forms a fitting conclusion to the eclectic review attempted in this book. In his own inimitable style, it points us unequivocally to the future.

“I am very glad to be here. Yesterday for a moment I was not so glad when I was presented with the OECD’s document *Education Policy Analysis 2001* (OECD, 2001*d*) because when I opened it I saw that it had already dealt with what I thought was going to be my opening and central point. Fortunately I think that this just gives me the grounds for building on what is in this document for which I really want to congratulate your research organisation. I urge you to consider the document seriously for a number of reasons; one of which is that the world of education is seriously lacking in the attention it gives to developing any sort of vision of the future. There has grown up a tradition of solving the immediate problems that face people right now and producing incremental improvements, but very little effort is given to serious planning, for what the world is going to be like in ten years.

Education planners differ in this respect from modern industry. For example, the papers this weekend were full of news about Boeing’s release of their plans for producing an aeroplane that will not even have a test-flight for another ten years. In some spheres of activity people are used to thinking the world is going to change. In education they don’t. I think if we want to see radical deep change in education we not only have to break that habit and put effort into thinking about the future, but also understand why this particular culture has developed in the education world. I’m going to elaborate somewhat my theory of that situation.

My theory concerns the system that we have in schools. By system I mean everything from the fact that schools are organised with segregation of ages – first grade, second grade, etc. – and that there is a particular kind of curriculum. The whole lot, content and methodology, is an accurate reflection of the knowledge technologies of the late nineteenth and twentieth centuries. The reason why education reforms in the twentieth century never produced much change was that the system was in equilibrium with the technological infrastructure that existed, and with the needs of the society. So it is not surprising that attempts to change the system did not really work. We now have a radically different kind of technological infrastructure to support learning, and our rapidly evolving society has radically different needs; these are the two themes I am going to develop.

What I like especially about the OECD document is that it does something that is rare: it tries to present six alternative scenarios for the way things might develop. I think it extremely important to keep doing that, and so I am going to step beyond those scenarios and build on them. None of us has a crystal ball to foresee the future, but I think there are some aspects of the future that we can be sure of and some aspects where you can be sufficiently sure for it to be worth exploring in detail and putting real resources into it.

One thing I think certain, which is not reflected adequately in the scenarios here, is that at some point in the future – my guess is in less than ten years – every student, every child from pre-school days will have a personal portable computer. They might not look like the computers we have today, but they will be at least as powerful or even more powerful. That is not a recommendation, not a prediction; it is a statement of fact of what will happen. If you look at it in many different ways, including the trend of cost of this sort of technology and the spread of the technology into society, it is going to be there. Whether it happens in five years or fifteen years might depend on you, but it is going to happen in something like that sort of time. So I think this is something that has to be incorporated in any scenario of the future.

Why is it not emphasised as much as it might be in these scenarios? I suspect because the writers of the scenarios have not had the kind of experience that I have had, which leads me to believe that this kind of technology will radically change the way that people learn what they learn.

This is perhaps the most important point I want to make here today, that generally the education world is misunderstanding the role of these technologies in many different ways. One way is that it thinks in terms of more efficient or better achievement of the same learning goals. I want to try to convince you that it is worth thinking that what children will learn will be very different. This is something to which hardly any attention is being paid and no resources are being devoted; this is something that I think we are going to regret on a worldwide scale.

So now as a little warm up I would like to ask you to consider a parable. Imagine a country that has a highly developed culture: poetry, philosophy, science, mathematics, but nobody has yet learned to write; it just hadn't occurred to them to have pencil and paper or even to write with sticks in the sand. One day somebody develops the idea of written language and the pencil and paper are invented. Very quickly this thing, which becomes known as information and communication technology, ICT for short, is picked up by scientists and by world traders. It has a big impact in those areas, and after awhile somebody wonders why we don't introduce this into our schools. These being cautious people, they decide that it is too risky to give every child one of these new technologies so they put one pencil in every classroom. "If that produces good results", they thought, "we'll maybe produce two pencils in the classroom", and so on.

Well, now we think this is very funny because we know that the role of writing in our culture is much deeper than anything that could develop through one pencil in the classroom, or even six pencils in the classroom. The pencil is deeply embedded in our way of life and thinking from childhood, so it becomes a deep and integral part in the way we think and the way we do everything. I believe that it is absolutely certain, and I invite you to believe that it is sufficiently possible to be taken seriously, that digital technologies will have as important and deep a role as writing, the pencil and paper have had. To develop that role it is no good thinking of putting one computer in every classroom or six computers in every classroom as a step in the right direction: it's no more a step in the right direction than climbing a tree is a step in the right direction towards space travel. In fact it is not only a very tiny step, it is a step in the wrong direction. What our schools are learning to do with this technology is not to use it for radical change in teaching but to use it to support what has already been done in twentieth century learning. In other words, teachers

are being trained, and we spend a lot of money training them, to neutralise this technology, to undo whatever powerful effects it can have, which is a waste, to say the least.

Now, to amplify that thought, which is my main intention here, let me go back to this imaginary country. I notice that these people who were suspicious of putting pencils in large quantities in the hands of children might have had some reasonably good arguments that we don't think of since we think it is funny. Let's take some examples. There was serious opposition to this new-fangled technology, because the thinking was that if children became dependent on writing they would lose their memory power. That serious argument was advanced by Plato. We may know that what you can do with writing more than compensates for that loss. However, for these people who did not know what you could do with writing, it was not at all obvious that the benefits would compensate for the obvious disadvantages.

It was not only memory power, they were suspicious of the idea that this new technology was leading peoples to do mathematics in strange ways that the teachers and parents did not understand. It is impossible to understand that when you think of what you learn in elementary mathematics, it is mostly about written mathematics: when you multiply numbers you write them one under the other and go through a ritual which we were all programmed at school to perform without thinking. Different ways of representing numbers require different algorithms. Very little attaches to how these representations express the mathematical essence. Now the people in the country of the parable did not know anything about that and looked on what we take for granted with great suspicion. We could spin out at great length the various aspects of the written culture that they could not even suspect. For the writing culture to become a powerful thing many inventions had to be made: an encyclopaedia, a dictionary, and so on. I think we are in this situation with the new technologies. The idea that you just dump this new technology there and its power manifests itself is just basically wrong for reasons not really different from those cited by the sceptics in my story. It needs time and resources to develop these different ways of doing things, different ways of learning.

Now, one more parable, this one about professors of education in the middle of the twenty-first century who, looking back at our times, give their students

a question to consider. Why, at the beginning of our century, when the biggest change in learning ever was about to happen, were the important countries in the world taken by a frenzy of preventing that change, by establishing tests and standardised curricula? Many measures – that cast in cultural concrete, so to speak, the knowledge of a previous century – made it much more difficult to explore any development of new kinds of knowledge, new things to learn and ways to learn them.

You can invent many theories to explain this paradox which you will recognise as true to life, especially in my country the United States. Personally I think the real reason is that the proponents of the status quo in education see an end to their way of doing things, so as the last twitch of the dying dragon's tail they close ranks. Whatever the theory adopted one should consider whether certain acts are of a nature to prevent the evolution of powerful educational developments. We don't have to prove that they will have this effect, but the possibility should be factored into the planning.

Coming to less fable-like aspects of understanding and misunderstanding this technology, I want to pick on a semantic point. It's universally called Information Technology to which sometimes the C is added, Information and Communication Technology. There's something very misleading about that, and it's worth digging a little deeply into why that image has taken hold of our imaginations when we think about its use in schools. First of all to have a more general name I am going to use the term *digital technology* to stand for everything that you can do with computers and microcircuits and so on.

When we look around the world, what are the uses, what are the roles of digital technology? One of them, and the one most visible to the general public, is getting on the Internet and getting information. I can find the stock prices, I can get the latest news. It's like television and like the newspaper. It's serving as an information medium. No doubt that's an important part of it, but in the actual world it is not all. In your automobiles, for example, there are microcomputers – there might be six. In the new international space station up there, which I'll refer to again in a little while, are thousands of them. In these big projects digital technology is not there as a source of information, but as a building material. It makes possible the building of things to a complexity that was previously unimaginable. So when we think of digital technology there are two aspects: there is the constructional aspect and the informational aspect.

Now let us look at education. In education also we can distinguish an informational aspect. Of course part of education is giving information to young people, but it's only a small part. Critics of the educational system in the twentieth century even before thinkers like Dewey, Piaget, Vygotsky, thinkers like the contemporary neuro-biologists who are studying the brain, indeed many people who have looked at the problem of learning, find our system at fault. They have recommended a method of learning based more on experience, more on doing projects and less on getting facts and knowing the right answer.

None of these suggestions has actually had a really deep impact on the practice of education. I think an important reason is that there was a lack of an appropriate infrastructure of technology to support their ideas. Dewey could say children should learn by things that should interest them, that are rooted in their own experience, but what if there is no activity of interest in which there are deep mathematics? Are we going to say the child should not learn mathematics? Some people have said that, but obviously that didn't really catch on.

The fact is that with the kinds of things that you could do with mathematics in the twentieth century there were very few which would both resonate with the interests of children and at the same time touch deep mathematical concepts. Of course you can send them out to measure the playground, but this is shallow mathematics and who cares anyway? This is where there is a huge change.

I'm going to give just one example of a kind of activity that I've been engaged with now for thirty years, but recently it has become something that has moved out of the laboratory and is involving maybe a million or so children of the world. This is giving children the opportunity to build robotic devices and to programme them. The Lego Company is producing the latest version that has gone round the world. There is a little computer that is called *MindStorms* that can be programmed by a child and built into a model. The model can then be programmed to do things like walk around, make music and respond to you. I saw some little girls do something that took me completely by surprise, which was to construct something they could dance with. I had never thought of that, maybe not being a little girl. The interesting thing is that I'm talking about seven-year-old, eight-year-old children, who invented a use of this computer that nobody had thought of before.

In certain classes it is girls who are way ahead of the boys in mastering technology and being sophisticated about it. The girls try all sorts of things, but the boys just want to make something fast and strong, so they build straight ahead. It's a change in gender relationships. I'm not saying that doing robotics is the answer. It's just one tiny example of digital technology being used constructively, not as an information medium. It made a real difference to the way in which some people learned and how their teachers saw them, because no one who has seen this any longer believes that girls are less attracted to technological fields or less capable of working in them. This is a deeper use, a deeper impact than the informational aspect.

Now let's step back. In the public view of digital technology there's the informational aspect, Internet, Web..., and there's the constructional aspect, the space station and so on, which most people don't have much to do with. The public view is almost exclusively of the informational side. In education there is also the informational side and the constructional side, but the informational side is the one that fits the conservative idea of what school is about. The constructional side is more radical and involves more change, so it's not surprising that people prefer to focus on the informational side.

Education and the popular view reinforce one another on the informational side of this technology. Our view of what the technology is going to do in education becomes dominated by an informational aspect, which is a dangerously bad thing to do. The real value of this technology is to open up a vast, unprecedented, and up to now unimaginable, range of activities. These both connect with the child's desires – what children love and like to do – and with the deepest ideas of science, culture, history, project management and entrepreneurial thinking and whatever. They are deep ideas of a huge range, and they are the interests of children.

So to round this up, what is the problem with school as we have moved into the twenty-first century? Society is changing with a rapidity that accelerates, but school has changed hardly at all. The gap between school and society increases. This in turn produces a sense among children all over the world that school is not seen as a bridge to the future, but as a bond to the past. I think that the disaffection and the problems with schools everywhere are because of this gap perceived by the children. There is a tendency particularly in the United States to say our schools are getting worse and worse, but they used to be very good, so let's go back to the way

they were. This is a way of aggravating the disease you're trying to cure. We have to find ways to make schools very different.

I've given some examples of how constructional use of the technology can, in principal, turn into powerful experience for children that are rooted in a phenomenon. You can observe worldwide a love affair between children and computers. It's amazing, everywhere in the world. I've worked in countries in Africa and Asia and Central America, and everywhere there is the same response of children to this technology – they love it. We don't have time to go into the reasons, but it is a fact, and if we don't use this fact we are selling our children down the river.

In conclusion I would like to make a few observations about things to do and who is responsible. It would not be right to fail to mention the responsibility of the computer industry. The computer industry has chosen to translate technological advance into more and fancier computer power at approximately the same price level. That technology could have been translated into somebody saying, "OK, we now have enough power to transform learning beyond recognition, let's make it less expensive." If we had wanted to do that, by now, I calculate that the cost per child per year of having a portable personal computer would be somewhere around ten dollars, which any country could afford.

Somebody has got to break that vicious circle. Some country has to decide we are going to create an educationally oriented computer industry. Although there's all the talk about cheaper computers, when you look behind it they want to give an emasculated computer, a purely informational device without any of the powerful constructional aspects. I think that it's a responsibility where the OECD could play a role, and you as ministers of education could play a role to open the door. I don't know who will do it.

Going around many countries I find a curious division. There are developing countries where people really want to see change, but they don't have the resources. Back home in America I find there's complacency. Everybody is complaining about the schools, but they are basically satisfied with the system as it is. They do not really want to see deep change. I don't know who is going to break out of that. Is it a member of the OECD or perhaps one of the partners? I have just come back from Russia, which is an interesting example of what you might call the only developed developing country in the world. I was really struck by how many people

there have given thought both to the foundations of education and the need to find a niche in the industrial world. Somebody is going to break out of this vicious circle, because although human stupidity and reticence and conservatism can continue for a certain length of time eventually it cracks. Eventually when policies are radically out of touch with the needs of the world somebody does something about it. So basically I feel optimistic.

I am going to tell you one last story. Back in the 50s the United States was somewhat embarrassed by the fact that the fastest transatlantic ocean liners belonged to European countries. France and Britain had faster ocean liners than they had, and at the time, of course, crossing the Atlantic was the essence of important travel. Ministers and all important people were into crossing the ocean quickly. So American resources of technology and money were mobilised and led to triumph. They made the fastest boat in the world, the S.S. United States. In the very same year the first commercial jet plane flew and it became totally irrelevant which boat could travel faster across the Atlantic. I'd like you to hold that in your minds when thinking about school. Are we trying to perfect an obsolete system or are we trying to make the educational jet plane?"

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