gest that democratic schools are the best tools for the education for autonomy.

If education is training, then training for autonomy should include training for skills for the enhancement of autonomy, moral but also economic. The transmission of skills may then replace the traditional transmission of knowledge. The following questions may then be raised: How much knowledge is needed for effective training? What skills are essential for what other skills? How can education be viewed as vocational training? The availability of pocket calculators renders detailed training in arithmetic unnecessary, unless experience shows that mathematical training requires it. Some familiarity with the national ethos is essential for the reasonably competent citizen (though with no need for indoctrination). The ability to make a simple instrument is essential for becoming a physicist just because simple laboratory operations are executed with the aid of high-tech instruments and computer programs.

The split of schools to vocational and scholarly should vanish, as well as their isolation. Educational bureaucracy and its elitism are growing. Combining learning with industry is becoming very attractive, especially in Sweden, where job improvement, job rotation, and semi-autonomous teams are increasingly common, showing how to close the gap between the academy and industry. Study, work, and play are different activities, yet their separation is unnecessary and harmful.

Reform should transform teachers into coaches. This will remove indoctrination. The end of training in general and of every specific program should be stated and debated. The reduction of indoctrination will invite the inquiry into the possibility of prolonging adaptability quite generally. Perhaps this is just a dream, but it is too exciting not to examine it empirically.

Overcoming discrimination will eliminate barriers to adjustment. The supreme source of discrimination is schooling. This will change as schooling ceases to instruct knowledge and instead train for skills. Scholarly skills and diverse daily skills and artistic skills will be then integrated. This will go very well together with pluralist participatory democracy.

"It's Pretty Scary": The Traumas of Change

Paul Black

Innovation in education is a stressful and often painful process for all involved, and particularly for teachers. The quote in my title came from a teacher involved in one of 23 innovations studied in detail in a recent Organization for Economic Co-operation and Development (OECD) study of the processes of change in science, mathematics, and technology education across 13 of its member countries. I believe that a general distillation of lessons drawn from the results (Black & Atkin, 1996) contains many lessons of importance for school technology.

It is clear that, for countries all over the world, technology is "the new kid on the block" in the school curriculum. This new kid is exciting, but difficult. The JISTEC 1996 underlined this view: the numbers, over 800 delegates from 80 countries, were evidence of growth in interest, while the diversity of the presentations, and of the conceptions of school technology underlying them, was evidence of the excitement and of the difficulties. Given that, in many countries, school technology is either new or recently re-born, it follows that its future in schools depends upon the implementation of innovation and change, and so we have to look hard at the prospects for success of innovative change. Here the omens are not encouraging: the panthen of curriculum revolutions is crowded with the gods who failed.

One motivation for international study is that countries naturally look at the ideas and practices in other countries to see whether they can improve their own systems. There are many dangers in attempting such transfer, and the OECD work signaled the need for a more complex understanding of innovations, one which tries to understand how their growth depends on the environment of their country's particular culture. However, six common themes emerged across the OECD cases as key issues. I shall discuss these in turn before drawing some general conclusions.

THE IMPETUS FOR CHANGE

Some countries are driven by "demons"—standards are falling, other countries stand higher in the league tables of the Third International Mathematics and Science Study (TIMSS), international competitiveness is threatened. Some press for students to be better prepared for work in employment, with well-developed general skills so that they can be flexible, learning for today's task but well able to learn afresh as technology transforms tomorrow's task.

Paul Black is Emeritus Professor in the School of Education at King's College in London, United Kingdom.

A different impulse springs from the need for future citizens to take effective control of changes in their societies, capable of critical and well-informed judgment, and with a well-developed awareness of values involved in any social change. A statement from the USA science education reform project, Project 2061, underscores the point as follows:

> The terms and circumstances of human existence can be expected to change radically during the next human life span. Science, mathematics and technology will be at the center of that change—causing it, shaping it, responding to it. [Scientific literacy] is essential to the education of today's children for tomorrow's world. (Black & Atkin, 1996, p. 15)

Changing Subjects

The studies show that the nature of school subjects is changing in profound ways in many countries. For example, in science there are notable shifts, one from presenting science as disembodied truth to describing it as the product of real people, the other from emphasis on pure research to stress on complex fields of application. The latter leads to a focus on interdisciplinary problems and so naturally promotes a trend towards teaching all the sciences as a single unified subject or as a closely coordinated set. This emphasis on the practical can also lead naturally to discussion of the wider effects of practical applications, and some teachers use these opportunities to introduce discussion of issues of social choice and moral values into science classrooms, although many other science teachers do not feel comfortable handling such discussions. There is also a rather different emphasis on rethinking the presentation of science to students through their own experience of practical investigations so that they can experience its work in a more authentic way.

These trends, taken together, amount to a re-conceptualization of school science in which the definition of the subject is no longer determined by the priorities of research scientists but is fashioned by a broader educational agenda in the control of teachers and, to a degree, the wider public. Such re-definition of the subjects is bound to have an impact on the role of technology education and on its relationship to science and mathematics education. The new approaches would seem to support a broad approach to school technology giving high priority to the need for better informed citizens and lower priority to the needs to train future engineers or craft experts.

Teaching and Learning

Changes across many countries are being driven by changed ideas about the ways in which students can learn most effectively. The traditional "delivery" model of learning was underpinned by a set of assumptions about learning, notably that:

- "knowing that" must come before "knowing how";
- the effective sequence of learning is first to receive and memorize, then to practice routine exercises, and only then attempt to apply;
- it is better to teach at the abstract level first and to leave the business of application in many different contexts to a later stage;
- motivation is to be achieved by external pressure on the learner, not by change in the mode of learning or the presentation of the subject; and
- difficulty or failure in learning arises from an innate lack of ability, or inadequate effort, rather than from any mismatch between the teaching and the needs of students.

These assumptions are no longer accepted. The emphasis now is on constructivist approaches, which imply that students must clarify and express their own beliefs and then be challenged to change them so that learning becomes a process of individual active construction of meanings.

In this scenario, it is clear that technology can play an important role if it is defined as the subject in which real problems are tackled in their own terms, the need for a solution being pursued by calling on whatever resources of materials, knowledge, and skills appear necessary, irrespective of which school subjects own or can supply these resources. In these terms, it can become the most radically cross-curricular of "subjects."

Assessment

It was notable that as the case studies developed, it seemed as if many of those pursuing innovations did not want to incorporate ideas or initiatives about assessment in their work. This may have been because it was seen as a threatening or, at least, problematic area. Assessment commonly has a negative image because summative assessment with its high stakes, both for grades, or certificates, or university entry, and in school accountability, dominates teaching and, sadly, also narrows its scope by the use of cheap measures of performance.

However, there were some bright spots. Studies in Norway and Spain developed self-assessment by pupils, which improved their sense of control and responsibility for their learning. In France, new national tests provided diagnostic information of value to teach-

ers. These moves were emphasizing two developments. One is that the role of pupils in their own assessment is essential if they are to take fuller responsibility for their learning overall. The other is that teachers' skills in day-to-day classroom assessment need to be improved, both to enhance learning and so that eventually teachers can be trusted to take an enhanced role in high-stakes assessment. For technology, where short external testing cannot reflect the aim of developing practical capability, such developments will be essential.

Teachers in Change

Change is often deeply disturbing for teachers. It can require that they take risks in establishing new ways of relating to their students, it can threaten the teacher's authority and pedagogic expertise in the classroom because it demands new ways of working with learners, and it often requires a level of subject competence that teachers do not have.

If teachers are to cope successfully with change, several conditions seem to be important. These are briefly set out as follows:

- Dis-equilibrium: Teachers must themselves share a dissatisfaction with present programs and see the need for improvement in their work.
- Exposure to alternatives: Teachers need to be convinced that there are better approaches.
- Existence proof: The feasibility of the implementation of any proposed changes, in classrooms like their own, has to be demonstrated.
- Modeling: Teachers should be in touch with peers who are operating the innovation, who can serve as models for them when they prepare to put the innovation into practice in their own classrooms.
- Support: Teachers have to be given support, within their own district and particularly in their own school—a support that recognizes that innovation cannot be risk free and that will allow for, and help them to cope with, early problems and even failures.
- Experimentation: Opportunities to try out new ideas and methods with groups of students from outside their own schools can be particularly useful.
- Reflection: It is hard to assess or understand what is happening in a busy classroom while one is on one's feet trying to manage the situation—opportunities to sit back and reflect, alone and with colleagues, are essential if lessons are to be learned from one's first struggles with an innovative approach.
- A role: Teachers have to be treated as partners in the formulation as well as in the implementation of reforms, and they have to be given flexibility to adapt as they learn how to implement broadly specified targets.

The Student's Perspective

It became clear during the studies that students could offer very useful insights on the processes of reform and that change could often be stressful and disorienting for them. Changes in the definition of the subjects meant that the image of the subject that they were acquiring from the school's presentation had to be changed, sometimes in a radical way. At the same time, their experience of learning might also have to change so that they would have to become accustomed to new ideas about what constitutes learning—and therefore learn to behave differently in their classrooms.

A teacher in Spain described the experience of working with such difficulties with students as follows:

> Children receive so much information, and at such an incredible rate that they are unable to assimilate it, and this is precisely what is happening with their learning. [As in formulating] hypotheses, the conclusions and analysis section that come at the end of each activity proves to be very difficult with students. This is because they simply swallow everything. . . . They are just like the television news. They give information but they don't analyze it. (Black & Atkin, 1996, p. 151)

This extract illustrates a feature that was common across several reform programs—that students needed particular help in assuming greater independence in their learning. Such independence meant that they had to break the habits of passivity and of dependence on their teachers.

STRATEGIES FOR CHANGE

Several common features emerge fairly clearly from this summary as follows:

- The distinction between "top-down" and "bottom-up" reforms describes two ends of a spectrum rather than a dichotomy. Neither approach, on its own, will guarantee success or lead to certain failure.
- Reforms cannot work if they are too radical. Procedures and targets that are completely foreign to teachers will be seen as threats, and they may easily become demoralized and resistant. It is important rather to build on existing strengths.
- It takes teachers and schools considerable time to adapt to reforms, and it is both unrealistic and unhelpful to expect

changes to succeed at the first attempt. The lessons that teachers learn in practice should be fed back in a process of evolution of a reform.

- Each reform should be considered in relation to the particular context of culture and tradition in which it is made concrete, and any reform should be regarded as an organic whole. The machine metaphor characteristic of the age of "the enlightenment" does not apply. Likewise, the six themes discussed are intertwined within any actual innovation.
- The complex interactions implied by the previous point are an enduring feature. Any change that works with one aspect only of an educational system will inevitably affect, and be affected by, other aspects, so planning must be systemic.

A systemic approach does not imply that any reform has to aim to change every possible aspect of a system—change would be hardly possible if this were true. The lesson is rather that any plan first has to formulate a broad picture of the educational system. Then, in the light of this picture, a boundary has to be established for the proposed innovation. All those elements inside the boundary should be tackled in a coherent and mutually supportive way while all those elements outside the boundary will be accepted as they are, so that the innovation will have to adapt and accommodate to any influences that they may exert. A suitable metaphor might be that of defining an ecological niche in which the reform plant may flourish. It follows that even a flourishing plant may not survive if it is transplanted into a different ecological system, or if the ecology is altered by changes outside the boundary.

Another aspect of a systemic approach is that a wide range of persons and agencies should be involved in educational innovation—with the corollary that they share responsibility for promoting and supporting it. Thus, parents, community groups, those working in media, museums and zoos, administrators, businesses, researchers, teacher educators, and publishers may all have a part to play.

Even if the advent of technology as a new subject were not a prominent feature of the scene, the picture that the studies paint of science and mathematics education being redefined and reorganized as schools try to respond—to changes in society and to new ideas about learning—is not one that is likely to settle down to equilibrium. It seems, rather, that as the pace of technologically driven social change is likely to be maintained, schools may be faced with demands on them that change more rapidly than they are able to respond, which is to say that education may never catch up. Given this prospect, and accepting the argument that the teacher stands at a focal point in the implementation of any change, it seems inevitable that educational systems will have to reconsider the role and work of teachers quite radically. For example, if teachers were to be given far more time free from classroom duties so that they could interact more closely with the world outside the school and plan their work accordingly, schools might be better placed to respond to change and to look more realistically to the needs of their students as they enter adult society.

If such considerations are important in the established areas of science and mathematics, they will apply with even more force to technology as a new or reborn school subject. While there cannot be any single recipe even for defining, let alone implementing, school technology as a new subject, it is clear that a modestly slow approach will be essential. Those anxious to promote this important development in the school curriculum should temper their enthusiasm and impatience with the realization that it is possible to build on modest success, but very hard to recover from ambitious failure.

Reference

Black, P. J., & Atkin, J. M. (Eds.). 1996. *Changing the subject: Innovations in science, mathematics and technology education.* Routledge: London.

Details of the case studies, with information about where to obtain the full reports, may be found in Black & Atkin (1996).