International research on computers in education - Willem J. Pelgrum

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The 1980s can be characterized as the decade of technology revolution in education. Although previous decades also found quite a number of new technologies introduced into schools (educational television, radio, audiovisual media, language laboratories, etc.), the introduction of computers was unprecedented in terms of expectations and hopes for quantum leaps in educational progress. In many countries, the technology fever rose quickly, so that by the early 1980s governmental programmes were started as a reaction to a fear of losing the technology race. Gradually, most developed countries introduced computers into schools, starting at the higher levels and filtering down to the lower-secondary and primary-school classroom.

In those developing countries lacking basic materials such as chalk, paper and pencils, there were on occasion projects to implement computers in the classroom (Hawkrige, 1990). In such circumstances, the often repeated arguments suggested computer technology might act as a catalyst to improve school learning dramatically. Even without governmental stimulation, a strong impetus remained to adapt computer technology to the classroom, so that many schools acquired computers on their own with local support from banks and industry. In the case of the Netherlands, nearly 50 per cent of all schools had acquired computer equipment on their own prior to the start of government programmes designed to introduce computers in education.

At first glance, the diffusion of computer technology into schools may seem relatively straightforward, but first results from an international survey of educational practice show a different picture. The use and application of computers in school is a very complicated process, expensive and beset with problems, demanding large investments in time from educational practitioners when the goals and benefits of such innovation are unclear. While the computer revolution in schools was not about speeding up the learning process, it hoped to make knowledge more available and learning easier. Across high-and low-income countries, it was expected that the consequences of computers in education would reduce potential 'knowledge gaps'.

The findings reported below stem from the Computers in Education Study (COMPED), conducted under the auspices of the International Association for the Evaluation of Educational Achievement (IEA), which was carried out in 1989 in twenty-one educational systems: Austria, Belgium (Flemish), Belgium (French), Canada (British Columbia), China, France, Germany, Greece, Hungary, India, Israel, Italy, Japan, Luxembourg, Netherlands, New Zealand, Poland, Portugal, Slovenia, Switzerland and the United States.

This article sets out to examine some of the major findings of this COMPED survey. First, a short description of the study design is given, followed by a summary of main findings in relation to: hardware/software availability; computer usage; and problems with and attitudes towards staff development, administration, policy and gender shifts associated with adoption. The final section offers some possible next steps in answering questions about the proper role of computers in education, in schools, in classrooms and in the hands of students.

The computers in education survey

The major goals of COMPED, which is now under way, are to describe and analyse cross-nationally and longitudinally the ways computers have been introduced into schools and used by teachers and students. Furthermore, interest in cognitive skills and attitudes held by students and teachers with respect to new information technologies are felt to be important determinants of whether computers become widespread. Future technologists are already aware of the social rationale which prepares children to function as citizens of the new age; the vocational rationale, which prepares students to function as professional workers in a technological society; the pedagogic rationale, whereby computers may be used to improve instructional learning efficiency; and the catalytic rationale, whereby computers may bolster economies of scale in such areas as improved management and administration of schooling.

COMPED can be divided into two stages. During Stage 1 (1987-90), questionnaires were developed and data collected from teachers and principals in elementary and lower- and upper-secondary schools in twenty-one countries. During Stage 2 (1991-94), measures from the first stage were revised and readministered along with actual tests of computer knowledge and hands-on use by students.

The measures obtained from Stage 1 of the study were based on a conceptual framework characterizing the educational system in terms of decision-making at the macro, meso and micro levels through the identification of those factors found contributing to adoption success. These factors, which were identified from the literature on educational change (Fullan et al., 1988), included quality, clarity and relevance of objectives; innovative characteristics such as content, materials and instructional strategies; support for leadership and staff development; and evaluative experiences gathered through feedback.

The framework reflects the hierarchical structure of most educational systems found in the world, but also acknowledges that decisions which promote or inhibit the implementation of computer-related curricula are made at all levels of the school system and may cause discrepancies between the decisions and expectations of educational administrators, policy-makers, principals, teachers and students. An identification of these discrepancies may in itself be an important starting-point for improving computer technology measures in education.

Data from Stage 1 reported here were collected by means of questionnaires given to 70,000 respondents (principals, computer co-ordinators and teachers) from primary and lower- and upper-secondary schools in twenty-one educational systems. (Additional details can be found in Pelgrum and Plomp, 1991.) Overriding questions concerning the relevance, clarity of goals, complexity and practicality of introducing computers into schools must be raised now if answers are to be forthcoming. The twenty-first century is drawing near and the computer's role, while still not clear, will surely have a profound impact on classroom learning. The pattern changes across rich and poor countries will have implications for the distribution of knowledge worldwide.

Availability of computer hardware and software

A major question COMPED asked was about school access to and use of computers. The average number of computers found in schools gradually increased during the 1980s, although in some countries sudden jumps could be observed as a result of governmental stimulation programmes. For example, the quantity of hardware (expressed as the median student/computer ratio per country) increased for each additional year that the programme continued. In general, while overall computer availability grew in the 1980s, in some countries, such as Switzerland, growth was rapid, while in Luxembourg availability grew less noticeably. At the elementary-school level, computer availability in Portugal, France, the Netherlands and New Zealand ranged between two and four while in Japan ten computers per school were found, and in Canada (British Columbia), Israel and the United States, sixteen to eighteen computers per school could be counted.

In the majority of schools around the world, computers are located in special computer rooms. However, as one moves down the educational pyramid, there is a clear trend towards placing computers in classrooms rather than the special computer laboratory. This seems natural, since in the primary grades computers can be used less formally as a learning tool than in, say, the upper-secondary curricula. Likewise, teachers tend to organize computer usage in such a way that two to three students share available computers, even if this results in splitting the class into groups working on computers and groups performing other learning activities.

Not surprisingly, data from Stage 1 show that, during the 1980s, computers were used for instructional purposes in most lower- and upper-secondary schools, while primary schools deployed computers for both academic work and educational play.

Considerable variation between countries with respect to computer software availability currently exists. Educational software used for practice drill and tutorial and educational games, along with word processing and database programs, dominates in all levels of schools. Furthermore, there is a positive correlation between the use of computers in learning (educational tools) and the availability of instructional software (see Figure 1).

FIG. 1. Use of computers for learning versus availability of software in fifteen lower-secondary education systems.

How computers are currently used in schools

Findings from the international survey suggest that the most popular use of computers in secondary education can be attributed to teaching students about programming and applications like word processing, databases and spreadsheets. Many secondary schools in most countries established a Computer Informatics Curriculum, where students could learn how computers work and how they are manipulated. However, the use of computers as a tool to aid learning in existing subjects such as mathematics, science, language and arts was by the end of the 1980s still not very widespread in secondary schools. In only a few countries, such as the United States, did a significant number of teachers of mathematics, science and the mother tongue use computers intensively to assist with their lessons. In these cases, computer programs are used for drill and tutorials.

It seems that the proportion of exemplary teachers who integrate computers substantially in their everyday class activities was only 3 per cent. When looking at all subjects, survey findings show that the predominant subjects using computers in the primary-school classrooms are mathematics, the mother tongue and informatics. In lower- and upper-secondary schools, the predominant subjects employing computers are informatics, followed by mathematics and commercial studies.

With respect to teaching students how to use computers, most computer education instruction carried out in secondary schools takes place in separate courses. When not carried out separately, such teaching is part of mathematics classes. Drill and practice are very frequently mentioned as activities where computers can liven up the learning process. Here, it is possible to distinguish between 'learning with computers', in which activities such as computer-assisted instruction - both remedial and enriching - and testing via computers are highlighted in order to further knowledge about the subject-matter, and 'learning about computers', which implies learning about word processing, database programs and computer science. In the case of computers used to learn curriculum content, such activities correlate positively with years of experience using computers (see Figure 2) as well as with availability of educational software. Consequently, it takes a while from the time computers are first introduced into schools before learning activities that employ the computer can take root. This seems logical, since the first step must be to train students how to log on to computers and in general feel comfortable with the hardware.

FIG. 2. Use of computers in learning versus years of experience in computer use.

Problems associated with failure to adopt computers in schools

In generalizing results from all twenty-one countries, it was found that too few computers and too little instructional software were key constraints preventing the successful adoption of computers in schools, according to school principals, computer co-ordinators and teachers alike. These resource constraints represent a lack of basic infrastructure to support growth in computer use in schools. Another important constraint has to do with a lack of teacher knowledge and training about how computers can be used in instruction. Contributing to this lack of knowledge is lack of sufficient time to develop computer-based lessons. Finally, many principals in many of the countries argue that lack of financial support prevents their school and teachers from adopting computers.

Attitudes toward computers in education

As a rule, educational practitioners hold very positive attitudes about the use of computers in education. While school principals at all educational levels are genuinely in favour of their introduction, those principals in schools already employing computers hold more favourable dispositions towards computer technology than principals from non-using schools. Apparently, previous successful experience with computers in schools reinforces favourable attitudes towards technology. Positive attitudes held by principals can reinforce a favourable climate of receptivity towards computer adoption in the classroom.

Male and female principals do hold different attitudes towards computer use in classrooms, with men principals eliciting more positive responses. They were asked whether they agreed with such statements as the following:

- Computers are valuable tools to improve the quality of a child's education.
- Students are more attentive when computers are used in class.
- Computers in school enhance student creativity.
- I try to keep myself informed about technological changes.
- I would like to learn more about computers as teaching aids.

It appears that principals with more positive attitudes towards computer education tend to stimulate the use of computers in their school more frequently. Likewise, teachers holding more positive attitudes towards computer education are inclined to favour use of drill and practice programs, tutorials and computer-assisted instruction more than their counterparts who favour less computer technology.

One way to influence favourable teacher attitude changes might be to include pedagogical/instructional aspects in training courses, since the amount of information teachers receive in training courses about pedagogy and

instruction is strongly associated with attitudes about the educational impact of computers. Currently, little attention is paid to the pedagogical and instructional use of computers in teacher training.

Staff development and computer use in schools

Staff development, measured primarily by better in-service training, has implications for consciousness-raising in terms of getting principals, teachers and students to accept computers. Clearly, the greater the time spent by teachers working with computers, the greater the likelihood of the teacher integrating learning-with-computer and learning-by-computer activities into the subject-matter curriculum. One major point of the study bears repeating. Integrating computer use into the classroom is not easy. The use of computers in education is a complex innovation, and full implementation cannot be expected within a short period of time.

From the survey, we know the more time spent by teachers working with computers, the greater the likelihood that teachers will innovate. We also know that the computer knowledge and skill base possessed by teachers is significantly related to training received. Furthermore, the amount of training received and the type of topics covered in training are related to the degree to which computer usage is integrated in the curriculum. Therefore, it would be wise to look more closely at the types of teacher training necessary to strengthen teacher competency, especially training opportunities in the pedagogical and instructional aspects of computer use. To date, such topics are found infrequently in in-service training.

Administrative use of computers in schools

At all population levels, computers are used by school administrators, principals and teachers alike to ease the burden of bookkeeping tasks associated with schooling (e.g. student lists, grading, attendance, etc.). Earlier, some believed that the administrative use of computers by school staff for the very practical tasks involved in handling large amounts of data on students and teaching would gradually generate interest and demands for instructional purposes. In fact, the opposite is true. Computer use for instructional purposes and informatics has driven the demand for the administrative uses of computers in the school. Finally, when computer coordinators were asked about administrative priorities in using the computer, the school budget was consistently given the highest priority in all countries. More software and more computers were the next order of priority. Strengthening the present infrastructure seems to be more important than upgrading the system equipment.

Gender differences and computer adoption

A number of gender-related issues were raised in COMPED because of fears that technology issues, being similar to mathematics and science, might cause inequities in the way boys and girls perceive and use these new technologies. The study showed, for example, that the number of potential female role models found in schools who use computers are few, indicating that computer use in schools is dominated by males. These findings confirm the concern felt by many policy-makers - including educators favouring the emancipation of girls - who believe that the daily practice of computer use in schools too strongly suggests to students that such use is predominately a male activity, not suitable for females. Israel and Portugal are exceptions to this pattern but only at elementary-school level.

When looking at the type of role model provided by female teachers working with computers, the study found that female teachers scale their knowledge skills and expectations towards computers much lower than male colleagues. The largest gender differences between teachers are found in the field of programming. Surprisingly, female teachers indicate fewer problems with computer use than male colleagues. Females do have more organizational problems and view their lack of knowledge and skills as a serious constraint. It is not possible to offer one single explanation for this finding and, again, no major gender differences can be found for teachers with regard to attitudes towards computers.

When we shift away from role-model gender differences and look at the policies schools set, deliberately or otherwise, concerning equal opportunities for boys and girls, some differences arise. In a few cases, computer activities are explicitly organized for boys or girls, but this may arise where the school administrators wish to provide compensatory activities for girls, including attempts to find more female role models.

Only in French Belgium and France do a majority of schools indicate that they have a special policy that specifically promulgates equal opportunities for boys and girls, and this usually takes the form of training more female computer teachers and female computer coordinators. Schools seem to promote policies directed towards development of female role models for girls, but do little to instruct boys and girls differently in the use of computers.

Three conclusions related to making curricula gender-neutral can be drawn:

1. Variation in the application of computers seems to be more important for girls, although the software used in computer education courses is limited and female teachers are less apt to use a wide array of applications when software is available.

2. When designing new computer programs and program languages, LOGO languages appear more user-friendly to females, especially in upper-secondary schools. Currently, LOGO is used extensively in elementary schools, while BASIC is the preferred programming language in upper-secondary. The LOGO programming language was viewed as a major triumph because of the ease with which children could manipulate it to write programs.

3. It is necessary to avoid giving the impression to girls that computers should be used only for mathematics and science. Unfortunately, at present computers are used primarily in those school subjects.

What did school systems gain from this study?

Some results from the IEA Computers in Education Study presented above indicate that the continued diffusion of computers into school systems around the world seems likely, as in fact the second stage of the survey currently under way continues to monitor this process. The future of computers in education shows signs of both optimism and pessimism.

On the positive side, we see the new computer technology already available in many schools in developed countries. Despite complexity in innovation, educational practitioners and students appear very enthusiastic about adopting computers, even after severe budget cuts. In fact, it appears that student enthusiasm revitalizes teacher commitment, regardless of the additional time required to implement computers in the classroom.

On the negative side, the survey revealed much inequality in access to school computers. Some developed and developing countries are lagging behind in terms of computer availability. Moreover, once computers are in place, they tend to be used most frequently as an add-on to the existing curriculum rather than as a productivity agent which enhances the quality of learning. It is probably this lack of integration into the existing curricula as a productivity enhancer that poses the greatest challenge for the future.

As pointed out elsewhere in this article, there are several models regarding the aim of placing computers in schools. Learning about computers - the technical model - and learning with computers - the integrative model - represent two major conflicting goals. The evolution of these models over the 1980s shows that the technical model was predominant where the state of computer software and hardware forced students and teachers to write programs in BASIC, Fortran, LOGO or PASCAL to accomplish computer-related tasks. More recently, concern for the integration model has grown as a result of the ability to use more varied hardware and software.

The distinction between these two models is clearly reflected in the analysis of survey data collected from school principals and teachers in the late 1980s. The United States appeared to be in the forefront in respect of promoting computers for learning enhancement, and this finding will be checked against the results of the 1992 data collection that is currently under way. The 1992 survey will also provide answers to the question why some schools and teachers integrate computers more readily into the learning process. Currently, it is assumed that teacher competence and readiness play the deciding factor in the United States.

The analyses presented so far may be translated into several possible school strategies for future action. A preliminary list of four actions stemming from this study is given below.

MAKING MORE HARDWARE AVAILABLE TO SCHOOLS, TEACHERS AND STUDENTS

Although lack of hardware is mentioned by many educational practitioners, limited resources are the real problem. Schools cannot be expected to buy and replace computers to the extent that students can each have their own computer. Rather, one needs to think in terms of limited resources. From the current study, the best strategy to maximize computer use in schools involves curriculum flexibility, so that computers are always being utilized for both learning about computers and improving current lessons. As more and more computers are found in the home, it may be possible better to utilize the school as a resource centre to promote out-of-school learning. This raises problems of equity, and one may wish to consider how compensatory in-class programmes can aid students not having access to computers at home.

PRODUCING MORE HIGH-QUALITY INSTRUCTIONAL SOFTWARE

Caution is required when purchasing software, because the survey showed that teachers having equal access to software markets do not necessarily utilize software equally. In this regard, it is the teacher who employs software for learning instruction who is most likely to apply a wider range of software in schools. Educational practitioners

in mathematics, science, language teaching and other areas need to be made more aware of the kinds of software already existing, so that as the quantity and quality of software coming on to the market increase, they will be able quickly to take advantage of it. Consumer demand will drive the market and teachers need to be major partners in this movement for quality software.

TRAINING MORE HIGH-QUALITY TEACHERS IN COMPUTER USE

Quality training is imperative, but training organizers must maintain a balance between hardware/software availability and training demand. Until sufficient computers and a wide variety of affordable software can be made readily available to newly trained teachers, computers will have little impact on educational programmes.

GIVING TEACHERS MORE TIME TO LEARN ABOUT NEW TECHNOLOGIES

Providing more time to teachers sounds compelling, but must be tempered by the high cost of time. Strategies should focus on developing general teaching tools that do not require many individual teachers to spend time reinventing the wheel. Clearly, in systems with fairly uniform curricula, it should be easy to introduce general software learning programmes across the board, thereby allowing teachers to learn how to introduce the software activity into the classroom without wasting time in reworking the activity.

In summarizing the patterns of computer use in schools during the 1980s, one can see that most countries followed a quite simplistic diffusion strategy, based on the assumption that introducing computer hardware and software would automatically result in a fundamental change in the way students perform academic work in the classroom. The next stage in such a strategy allows for curriculum developers, textbook writers, teachers, media experts and others to focus on the role of teachers as the key element in promoting change. In this regard, an initiative by the European Commission to co-sponsor the development of an electronic bulletin board system throughout EC member states, in order to disseminate information on successful computers-in-education experiments to the educational community, is a major move towards building an infrastructure for efficient communication.

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