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Computers in Education

This entry presents an overview of the uses of computers in education. After a general definition of terms, two different approaches to categorizing computer functionality in education are given, and then factors related to realizing this potential are summarized. Finally, new functions that are emerging and factors that are likely to affect their realization are outlined briefly.

1. Defining the Domain of Computers in Education

Since the early 1960s there has been a steady stream of discussion and literature pertaining to computers in education (for an overview, see Hunter 1982). Thus, while the topic is not new, new developments, dimensions, and experience continue to proliferate. This overview will address the topic from a functionality perspective—how can computers be used in education, and what factors relate, either positively or negatively, to the realization of their potential uses? Only a limited sketch can be given here, but many of the key aspects are developed further in the more detailed sections of this Encyclopedia. First, the domain of discussion needs to be clarified, relative to the terms computer and education.

1.1 Defining the Term "Computer"

The term "computer" covers all environments of which a computer is an integral part. This definition thus ranges from the familiar stand-alone microcomputer to computers linked conceptually to other learning resources, and those linked electronically to other computers, electronically connected resources, other types of apparatus, or to all of these (see Moonen and Collis 1991 for an elaboration of these levels of complexity).

The essential factor is that the user is interacting with a computer in a deliberate way (rather than as a consequence of using another piece of equipment, such as a telephone). Given the technological convergence of computers with other media, information sources, and communications technology, it is not realistic to think of computers as referring only to the familiar stand-alone unit. In this entry, the word "computer" will be used instead of more accurate, but cumbersome, nomenclature such as NCIT (new communications and information technology, the term used by the Ministers of Education from the 24 OECD countries at the 1989 Council of Ministers meeting) or "virtual computer" (Sawyer 1992).

1.2 Defining the Term "Education"

In this entry, the word "education" is used in a broader sense than merely learning and instruction. Education covers the conscious structuring of experience in order to facilitate learning and instruction, and also the communication and interaction which can lead to learning and instruction. It is thus not synonymous with the K-12 school system, but also includes higher education, vocational education, professional education, training, and educational environments outside traditional, structured educational institutions.

Thus, "computers in education" refers to the use of computers as mediators in the flow of information, communication, and instructional materials that occurs in, or relates to, educational situations.

2. Computers in Education: Perspectives on Function

The function of computers in education can be considered in a variety of ways, including: relative to types of use, and relative to the philosophical background and motivations underlying computer use in education.

2.1 Function in Terms of Types of Use

One approach to categorizing of the function of computers in education is to identify type of use in terms of the software used. The following description of learner-oriented and teacher-oriented uses is not exhaustive, and some types of use can be classified in more than one way.

Learner-oriented uses include structured, predetermined learning tasks such as the following:

(a) drill and practice and testing;
(b) tutorials (including "intelligent" varieties);
(c) educational games;
(d) simulations (some varieties, particularly those for training);
(e) "problem-solving" software (some varieties); and
(f) learning about the computer and its functions as goals in themselves.

Extensive research on these types of functions appears in literature from the 1960s to the present

(for example, Atkinson and Wilson 1969, as well as the seminal work of pioneers in the field such as Bork, Luehrmann, and Suppes—see Taylor 1980 for a selection of their early work). "Intelligent" tutoring and coaching, coupled applications of artificial intelligence and advances in student modeling, are areas of ongoing research and development (see, e.g., Mandl and Lesgold 1988, Wenger 1987). There has been much study of computer-based training, relative to the use of computers for skill learning in training settings (see, e.g., Dean and Whitlock 1988). Alessi and Trollip (1991) are a representative source of the considerable literature on tutorials, drills, tests, instructional games, and simulations.

The issue of if, or to what extent, computers in educational settings should be used to learn about computers themselves, rather than used as agents for learning experiences relative to other topics, has long been discussed (see, e.g., Tinsley and Tagg 1984), yet there is still no consensus on what the optimum level might be. In the early 1990s, computers are used in school settings in many countries, predominately in courses about computers (or information technology) rather than as agents for learning activities more generally (see Pelgrum and Plomp 1991 for an international survey).

Other learner-oriented uses include those in the educational environment, tailored to a particular learning task or content, but allowing flexiblity of use:

(a) simulations (some varieties, including some varieties of "microworlds");

(b) problem-solving software (some varieties);

(c) MBLs (microcomputer-based laboratory materials);

(d) electronically organized data sets in relational databases, hypertext-linked stacks, or "electronic books" (Barker 1992)—any of these data sets may be text-only or multi-media; and

(e) expert systems (some varieties).

Learner-oriented uses also include tools or content-free environments used for educational purposes:

(a) writing environments, including word processing and desktop publishing;

(b) database environments (not already organized around a particular topic or goal, as in the categories above—these may be on-line, or resident in local computer or local external storage);

(c) calculation, projection, and statistical software (including spreadsheets);

(d) programming environments (particularly LOGO);

(e) telecommunications-mediated communication environments (including those for messaging, bulletin boards, and computer conferencing);

(f) electronic environments for visual and audio production and manipulation (including environments for graphing mathematical functions as well as environments for supporting creative visualizations and compositions); and

(g) "cognitive tools" (such as cognitive mapping, idea organizers, and some other types of software, including expert systems provided their function is to extend cognitive functioning during learning in a constructivistic way).

These categories also have an extensive literature. For example, microcomputer-based laboratory tools have been widely discussed, and their characteristics relative to student learning analyzed (see Thornton and Solokoff 1991). The implications of experiences with LOGO programming have commanded long-lasting and widespread attention (see Papert 1982 for the seminal work, and Pea et al. 1985, for an example of the many sorts of subsequent analyses of LOGO experiences that have occurred). The investigation of the educational applications of telecommunications is also commanding international attention (see, e.g., Roberts et al. 1990, Mason and Kaye 1989). Finally, a rapidly emerging area of interest in computer applications in education is that of cognitive tools—computer-based tools that facilitate generative processing of information by learners in a way that "amplifies the learner's cognitive processing" (Kommers et al. 1992).

Teacher oriented uses involve the use of teacher productivity tools, and tools for resource acquisition and handling, and for communication, including

(a) all of the tools noted above for learner use;

(b) student management and record-keeping software (for various types of data including individual student performance records and data for accumulation in system-wide administrative information systems); and

(c) software for production of specialized types of learning material (ranging from print materials, such as puzzles or tests from test banks, to the production of demonstration materials, such as transparencies for overhead projectors or multimedia materials for presentations).

2.2 Function in Terms of Rationale for Use

A different way of categorizing the function of computers in education is to consider the rationale behind their use, rather than to group different types of software. There are many different purposes for which computers are used in education. Hawkridge (1990), for example, identifies the following

categories: (a) social—to prepare students in a general way, through computer awareness, for their place in society; (b) vocational—to give students skills related to success in future jobs or study directions; (c) pedagogical—to improve teaching and learning in traditional subject areas; (d) catalytic—to use computers as catalysts of significant change in some aspect of the educational system, including the learner; (e) information technology industry—to build up the local information technology industry either through large-scale stimulation of use of its hardware and software products or by the eventual supply of a work force experienced with local products; and (f) cost-effectiveness—to reduce the overall cost of education or improvement of its results in relation to the traditional system. These categories illustrate the range of functions of computers in education.

While Hawkridge focused on schools and goal-directed motivations, Willis (1991) examines the field of computers in education in terms of the different background traditions and orientations of those who take leadership roles in various aspects of the field. Willis sees six "models" behind computer use in education, each relating to "different perspectives, different traditions, and different definitions of the essence of educational computing" (p.335): the computer science model, the educational psychology model, the programmed instruction model, the instructional design model, the information center model, and the audiovisual equipment model. (To this list could be added the communications model.) A representative of these background orientations would interpret the functions of computers in education in different ways, or at least give a different order of importance to the ways in which computers could be used.

3. *Factors Related to Realizing the Potential of Computers in Education*

Just as there is an extensive collection of literature describing ways in which computers can be used in education, there is also considerable information about factors that affect the realization of this potential. Some of these factors can increase the likelihood of successful realization while others serve to complicate or block the realization (see, e.g., van der Akker et al. 1992, Sheingold and Hadley 1990). The factors form an interrelated system in which the status of an individual component is continuously affected by the status of many others (the "ecological framework" conception of Peled et al. 1992 is a way of conceptualizing this). Another way of conceptualizing the factors is to group them in terms of macrolevel, mesolevel, and microlevel influences on the implementation of computers in an educational setting (Pelgrum and Plomp 1991). The following is a reworking of Pelgrum and Plomp's approach in terms of a school-type educational setting; this approach can also be applied to training situations or informal educational settings. As with the categorization of functions of computers in education, the following list is not exhaustive and, in many cases, categories overlap.

3.1 Macrolevel Influences on the Realization of Computers in Education

These influences include the following:

(a) attitudes of communities (social, cultural, political) to the value of a particular function of computers in education, and their ethical/philosophical positions relative to priorities for education;

(b) the range of possibilities for computers in education relative to economic constraints and economic motives and pressures relative to decisions about various aspects of computer use;

(c) the direction, degree, range, and level of support relative to funding, leadership, coordination, dissemination, and stimulation of possibilities;

(d) the system for development, dissemination, and follow-up support relative to the resources and support needed for computer use in education, such as educational software, lesson and curriculum materials, appropriate teacher education, and hardware and related equipment; and

(e) the extent to which successful completion of a curriculum area, relative to system-wide norms for that area, relates to computer use.

These layers of influence form the embedding environment in which computer use in education is contained. Factors here are very much interrelated. For example, the availability of a certain category of educational software in a system depends on how the development and distribution of that software was organized, which in turn reflects a chain of economic, political, and organizational decisions operating within a particular cultural and social framework. As another example, society's attitude toward respect of copyright versus software piracy can have a significant impact on the emergence of a viable education software market. Without financial incentives for educational software development, a local industry will not naturally develop, and software availability will then have to rely on government subsidy, which in turn depends on policy and the expedients that shape it. More generally, the efficiency with which software development and dissemination is organized critically affects the availability, and thus eventual impact, of affordable resources in a system. (For further analyses of the macrolevel influences on computers in education see: Murray-Lasso 1990 for social and cultural aspects; Fullan et al. 1987 for

leadership aspects; Walker 1986 for curriculum relationship aspects; Moonen and Plomp 1987 for national policy and the organization of software production aspects; and Collis and Oliveira 1990 for policy and economic aspects.)

3.2 Mesolevel Influences on the Realization of Computers in Education

These influences may be broadly enumerated as follows:

(a) institutional framework relating to policy, availability of resources, and "social climate";

(b) support available to teachers relative to computer use, including provision for an in-house computer coordinator, and provision of adequate time and access to computers for teachers to develop personal skills and lesson preparation;

(c) organization of computer-related resources within the institution, relative to equity and ease of access;

(d) leadership characteristics of significant persons within the institution relative to support and stimulation of computer use; and

(e) general social and demographic characteristics of the institution, including its teachers and students.

Every educational institution has its own culture and history relative to computer use, and these are factors in the realization of any particular type of computer function (Fullan et al. 1987). In particular, the attitudes and support of the institution leadership have a strong impact on computer implementation within an educational setting (Cox et al. 1988). Organizational decisions, such as who gets access to school computers and for how long, and the procedures by which such decisions are made critically affect the range of computer functions available within an institution. The approach and insight of the persons responsible for computer coordination within a system also affect implementation. Moreover, the general demographic characteristics of the institution, including the level of experience of its teachers and students with computers or, more generally, with innovation in the educational setting, set a frame around whatever occurs in terms of computer use (Collis 1988, Fullan et al. 1987).

3.3 Microlevel Influences on the Realization of Computers in Education

These influences include the following:

(a) characteristics of the particular teacher and students in a computer-use situation, including background experiences, attitudes, and capabilities;

(b) organization of the learning experience in which the computer use occurs, including integration with other learning activities, and strategies for student–student and teacher–student interaction during the learning experience; and

(c) characteristics of the computer-related resources themselves, with hardware and peripherals as constraining factors, but with the instructional design of the resources a critical factor.

Much of what is written about computer use in education relates to these so-called microlevel considerations. Many books and resources suggest lesson integration and management strategies for the teacher, and the more sophisticated of these take into account the teacher's and students' background characteristics in terms of their being able to handle a different level of complexity in lesson organization (see Boyd-Barett and Scanlon 1990, Kearsley et al. 1992). The design of educational software is a field unto itself, with a voluminous literature on design considerations that is continually being expanded by the emergence of new functions for computer use in schools and new complexities of computer systems, such as those related to multimedia and interconnectivity (see Moonen and Schoenmaker 1992, Venezky and Osin 1991).

3.4 The Realization of the Potential of Computers in Education

A large amount of research and comment is available on the extent to which the potential of computers in education has been realized. In general, there is agreement that the meaningful implementation of computers in educational settings is a complex, difficult, and time-consuming process requiring much insight and support, in which the teacher plays a critical and central role. While many instances can be cited of positive effects of computers in education in specific settings, the overall impact of computer use in education has not yet demonstrated "results" relative to the goals of any of the six rationales identified by Hawkridge (1990) except, perhaps, the first category, social preparation. The massive influx of computers into educational settings has likely, through sheer exposure, raised the general level of awareness of computers and their applications among students and teachers. (See summaries of the literature in van der Akker et al. 1992, Collis 1991, Kurland and Kurland 1987.)

4. Emerging Directions for Computers in Education

Emerging directions for computers in education are

related to the evolution of technological possibilities, new conceptualizations of computer use in an educational context, and to the need for better understanding and consolidation of past experiences. Again these categories often overlap, and many different perspectives are possible.

4.1 Toward Interconnectivity and Integration

Technically, educationally, and socially there is strong movement toward interconnectivity with respect to computers in education. On a technical level, computers are increasingly being integrated with video and audio resources, and—through networks—connected with other computers and educational resources. Educationally there is a growing movement toward acknowledging the value of cooperative work, and "computer-supported cooperative work" is a multidisciplinary growth area. The conception of the world as a global village, reinforced by social and economic realities, is also helping to promote the movement toward interconnectivity in computers in education. Interconnectivity and integration also refer to the movement toward regarding computer use as an integrated part of the educational environment, integrated in terms of computer application in "traditional" subject areas, but also in terms of computers as a catalyst to stimulate more integration of subject areas.

4.2 Toward Pervasiveness as a Personal Educational Tool

Another perspective of integration relates to computer use becoming ever more integrated in study, work, and communication processes in education. Word processing, desktop publishing, computer-mediated communications, and access to electronically stored information are aspects of computer use that are increasingly becoming commonplace features of educational activity. The emergence of "cognitive tools" and "intelligent agents" (as a new metaphor for computers), accompanied by advances in natural-language communication between persons and computers, will have a pervasive effect on learning; however, their effects on education as an organized system will take considerably longer to become apparent.

4.3 Toward Clarification of Priorities

Finally, after more than a decade of extensive (and expensive) experimentation with computers in education, a tendency to appraise the benefits of various applications of computers in education relative to their costs of implementation in a system is emerging (OTA 1988). Given the limitations on funds and resources in educational systems, there may be less willingness to fund broad-scale exploration of computer use in education than to strategically fund areas with the largest predicted payoff. Thus, for example, there may be more interest in computer use in vocational and professional education than in primary and lower secondary school applications. (This is already becoming the case in Europe.) Also, a critical reexamination of the degree of government subsidy to educational software supply, or even overall educational computer use, is now taking place in a number of countries in which significant government investments in these areas occurred in the 1980s, such as the Netherlands (Netherlands Ministry of Education and Science 1992). Finally, the viability of some of the types of computer applications in education listed in Sect. 2.2 above may be doubtful if system-wide cost-effectiveness criteria are applied to their use.

See also: Computer-assisted Learning; Computer-managed Learning; Computers and Learning; Instructional Design Theories

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Computers in Education, Organizations and Journals on

The 1980s was a decade of rapid technological improvement, and as a result, there was a reduction in prices and a growth of personal computers in educational settings. The number of supporting organizations and journals increased dramatically. In 1993, there were more than 1,000 organizations worldwide dealing with computers in education and related areas. To select and filter from all of the organizations, they were first divided into two main categories: (a) institutions of further and higher education, and (b) other organizations with an interest in computers in education. The first category covers university departments, computing centers and special centers for software and hardware development and implementation in the education and training area (primary, secondary, and university level). The second category covers professional profit and nonprofit organizations (international and national) with a profile of activities related to computers in education.

Similar clustering can be found in Osborne's (1991) *International Yearbook of Educational and Training Technology*. The selection was undertaken by taking into account detailed descriptions of all these organizations and the existence in all large universities of specialized departments and centers. In the second category national organizations from a limited number of countries are given. The selection criteria were: the size of the country, the sphere of influence of the country, and the geographical representation around the globe. All organizations are listed in Sect. 2 of this entry with reference addresses. More information about organizational mission and major activities and publications can be found in Osborne (1991).