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Models of Educational Computing @ Home: New Frontiers for Research on Technology in Learning

YASMIN B. KAFAI
University of California—Los Angeles, USA
kafai@gseis.ucla.edu

BARRY J. FISHMAN
University of Michigan, USA

AMY S. BRUCKMAN
Georgia Institute of Technology, USA

SAUL ROCKMAN
Rockman, ET AL.

To date, the major emphasis of educational technology researchers has been the development and use of educational technologies within school settings. Noticeably absent has been research and considerations that focus on the home as a computer-based learning environment and potential connections between school and home learning. Given the increasing presence of computers in homes, the authors argue for an explicit research focus on the various ways that computers in homes can be used to create rich learning environments or extend school-based learning environments. To that end, this article discusses various models of educational computing in the home that are linked to learning in school, along with critical issues for consideration by researchers who choose to venture into this emerging area.

For several decades, the dominant focus for educational technologists has been the integration of computers and related tools into classroom or other school-based learning environments. An impressive array of different technologies has been developed and considerable information has been collected on how to implement technologies within classrooms and schools (for a broad review of educational technology research, see Cognition and Technology Group at Vanderbilt, 1996). These research efforts have been complemented by policy initiatives (Panel on Educational Technology, 1997) and corporate initiatives (CEO Forum on Education and Technology, 1997) that strive to provide a framework at state and national levels to accelerate and improve the introduction of educational technologies into classrooms. While the national press is mixed with respect to the benefits of educational computing (Education Week, 1997; Oppenheimer, 1997), recent analysis of the National Assessment of Educational Progress (NAEP) data highlighted the positive benefits of technology use in students' mathematics learning when coupled to particular pedagogical approaches (Wenglinsky, 1998). School is where students in the US have the most equal access to computers as computer ownership in homes is highly skewed towards families of European descent in the middle and upper classes (Hoffman & Novak, 1998). While there are still many challenges and obstacles surrounding the effective introduction of computers in schools—primarily equity issues in access, teacher preparation, and implementation—it is safe to state that it is no longer an issue of *whether* computers will be in schools but rather *how* and *when* they will become fully integrated into students' school learning experiences.

However, schools are not the only location where learning takes place. Children's homes are another prominent setting that feature not only personal computers but also interactive technologies such as video game consoles and set-top boxes. Questions related to the use of educational technology in the home have been unexplored for the most part. Recent surveys indicate that over 50% of all U.S. households have at least one computer (Ramstad, 1997). Many parents purchase computers expressly for their children's educational use. Access to the Internet has been one of the driving forces for this growth which is expected to continue in the coming years, especially as options for faster connections to the Internet become more common, through cable services and high speed telephone access. Greater access to home computers is being encouraged by increasingly less expensive computers (below $1,000) that invite moderate income families, often first-time users, to acquire technology.

Several important issues fuel the concern about trends in home computer ownership and Internet access. For one, school success is no longer considered to be solely the result of students' academic performances or effort in the classroom; parent involvement in school activities is seen as equally important (Coleman, 1987; Epstein & Dauber, 1991). Furthermore, the value of informal learning for building a foundation for school activities has been stressed repeatedly (Cole, 1996). There is evidence that technology access outside of school provides students, in particular boys, with a head start (Levin & Gordon, 1989; Linn, 1985). Given the importance of these issues, we can no longer treat the presence or absence of computers in children's homes as incidental to their learning in school, or as a luxury. Consequently, the design and implementation of any educational technology for learning will have to take into account the home factor, in one way or the other.

This article presents a brief historical review on the use of and research on educational computing in the home, and then lays out a framework that the authors argue can be used to shape a new generation of research on educational technology in the home. We also introduce a number of issues and challenges in doing research on computing in the home.

A BRIEF HISTORY OF RESEARCH ON EDUCATIONAL COMPUTING AT HOME

The idea of computers at home stimulated many early projections about the range of potential uses (Moses, 1979) but the home computer did not become a reality until the introduction of personal computers in the early 1980s. A small set of pilot studies examined how computers were distributed across socio-economic levels and the predominant computer activities in these families (Rogers, 1985; Tinnell, 1985; Watkins & Brimm, 1985). The most extensive study was conducted by Giacquinta, Bauer, and Levin (1993) in the mid 1980s and followed 71 families with children to document their computer use for two years through interviews and home visits. What we know from these studies is that the early-adopter families were mostly middle class, and while parents often used the computer for professional purposes, most children used the computer for game playing and only occasional homework activities, if at all. Educational uses were at best a minor aspect of computer use at home, and then for only a small group of families.

A few studies focused on potential benefits to students' performance in school from having access to computers at home. One study examined whether computer use at home benefited students of kindergarten age by comparing them to students using the computer only in school (Hess & McGarvey, 1987). The authors found significant positive results for students' reading readiness and keyboarding skills, mostly because the software provided for the home focused on reading activities. Computer ownership at home also impacted positively elementary students' achievement scores in BASIC and LOGO programming in terms of better homework and posttest results (Nichols, 1992). Another study looked at computer take-home options for elementary and middle school students and found positive academic results for writing activities in terms of quality and length (Rockman, 1995). Home computer access proved to be an significant factor in all these studies, yet further explanations provided by all the researchers point to other equally important factors such as teaching style, curriculum integration, and software content.

On the whole, research on educational home computing has been eclectic, following no particular trend. Over the past 15 years, various researchers and practitioners have pointed out issues in computers use at home (Caldell, 1986; Hunt, 1985) or potential connections between home and school computer use (Epstein, 1985; Schall & Skeele, 1995), but these discussions were only a sidebar to the larger research on educational technologies. It is only now, with increased computer use at home National Telecommunications and Information Administration (NTIA, 1998) and more widespread access to networks and the Internet, that we see a renewed interest in the development and study of home and school connections using computers. In these projects, computers at home are used in various configurations—as extensions to school learning environments or for independent learning activities (Bruckman, 1998; Duffield & McFarlane, 1999; Fishman, Kupperman, & Soloway, 1998; Kafai & Sutton, in press; McMillan & Honey, 1992; Rockman & Sloan, 1995; Rockman et al., 1998a). We will discuss these projects in more detail as we present our framework for the study of educational computing at home.

MODELS FOR THE STUDY OF EDUCATIONAL COMPUTING AT HOME

To date, research on educational computing at home in relationship to school activities, including that of the authors of this article, has begun to uncover and identify relevant and challenging issues. However, though progress has been made, we feel that this research is still in its infancy compared to other domains in which computers and learning have been studied. We have identified three models for educational computing in the home, each of which defines the relationship and use between school and homework in different ways:

- computers and/or software provided for general home or family uses that may be related to particular schoolwork but can be used more generally;
- computers and/or software provided explicitly for use with specific homework or curricula; and
- computers and software provided for students to carry and use between home and school (not intended for general family use).

There is an additional area in which computers are used for education in the home that we have chosen not to address at length in this article: home schooling. While it could be argued that home schooling represents a valid location for educational computing in the home, in this article we take the term “educational computing” to mean computing that is linked in various ways to learning that takes place in formal school settings. This is because schools face particular contextual constraints that home schooling does not deal with, such as large class size, limited length of school day and year, and so on. Computers have been suggested as remedies to many of the instructional challenges that schools face, and it is the more recent move to various forms of home-based computing linked to school-based instruction that capture our attention here. In other words, we look at the computer use at home as an extension of computer use in schools and examine ways these extensions may be accomplished. In this review, we pay attention to factors such as families’ socio-economic status and computer ownership, provision of computer hardware and Internet access, the curriculum integration, and the educational goals for the computer activities that have in the past been found to impact computer use at home.

Computer for General Home/Family Use Linked to School Activities

In this model of educational computing at home, the computer, software, or network connectivity is provided in conjunction with the school to foster greater engagement with the classroom. Examples of this model include the Buddy Project (McMahon & Duffy, 1993), and the NetTV project (Fishman, Kupperman, & Soloway, 1998). For the past 10 years the Buddy Project has provided personal computers, printers, modems and Internet connections to all families in selected 4th and 5th grade classrooms across Indiana. In addition, teachers in participating classrooms receive substantial preparation for and increased access to classroom technologies. The almost 10,000 Buddy Project families include a range of income levels in both urban and rural settings. While there was not an explicit curricular focus to the Buddy Project, teachers were encouraged to develop lessons and projects that would take advantage of the additional school computers, and build assignments with the knowledge that all students in the class had computer access at home. All family members took advantage of the home computer and, while students did use the computer for almost an hour per day for school-related work, most of the time it was used by others for the usual array of games, exploring the Internet, business-related activities, developing technology skills, and personal writing. When focused assignments were provided by teachers, the home computer became a more effective adjunct component of instruction and led to increases in school achievement, improved motivation and more positive attitudes toward school, and an increase in family activities. Reportedly, television viewing decreased as well (Rockman & Sloan, 1995; Rockman et al., 1998a).

The NetTV Project, which provided urban Latino families with Internet access devices such as set-top boxes, on the other hand, was designed with an explicit linkage to middle school science as part of a particular curriculum unit. The NetTV boxes were provided by the project with corporate support, and returned at the end of the project. In this sense it was tightly integrated with the curriculum, and so could also be counted under the second model which considers computer use at home for homework primarily. NetTV was targeted at Latino families with low-SES, a group that does not typically use the Internet, with the intention of using technology as a means to increase family involvement in their child’s schooling, thus increasing student engagement with school-based learning. Though the families had many difficulties in learning to use NetTV, a range of uses emerged in both educational and recreational domains. Students were able to use the Internet to involve their families in science learning activities, and also used the Internet for homework in other classrooms. Family participation in this activity was the highest that the school had seen for this population of students.

Both the Buddy Project and the NetTV Project provide computers for general family use, but with the intention of having that use contribute to some form of improved performance or relationship with school. The projects vary with respect to the type of technology used, and also with respect to the specificity of curriculum integration. Given that the basic premise in these projects is to provide a computational device to families who do not already have one, an important goal for projects of this type is to address social inequities concurrently with other goals, such as increased parent and student engagement.

Computers Intended Primarily for Homework

A second model for educational computing at home involves the use of computers or software for students to engage in homework connected to school activities. An example of this model is the Software Design project from UCLA (Kafai & Sutton, in press). In this project, a bi-lingual class of 30 fourth and fifth graders designed and implemented in teams instructional fraction games as part of their mathematics class activities. All the students had computers at home albeit in different platforms and models; the game design software, a version of LOGO, was provided by the school, as well as software to convert between different platforms. While all the students copied their schoolwork on a floppy disk, only 10% of students continued to work at home on their screen designs and programs. Several problematic issues were identified: (a) lack of platform uniformity between home and school, (b) lack of parental support and knowledge, and (c) students' difficulties with design activities as homework.

Another example is MOOSE Crossing, a text-based virtual environment, which is often introduced to students as part of school-based activities (Bruckman, 1998). Interesting variations in its use occur when students who have Internet access from home participate in project activities in the informal setting of the home. Students engage in this multi-user text-based environment while in class, and then continue their involvement at home. The project makes no explicit arrangement for computers at home, but the MOOSE Crossing software is freely available over the Internet, so students with computers and Internet access at home can use the system on their own. Bruckman and DeBonte (1997) found that students who have access at home have advantages when compared to their peers, and often become local experts for the system. Their greater time on task allows them to develop deeper expertise compared to their peers. In the classroom, these local experts frequently offer technical assistance to peers and can function as class role models. As a result, they often receive significant positive reinforcement from their peers, and are encouraged to deepen their understanding with additional home use. The benefits of home access for users of MOOSE Crossing seem relatively clear. Less clear is that the whole class often benefits from these students' positive contributions to the classroom as a learning community.

A third example is the Lightspan Project, which uses the Sony PlayStation as a platform for children to practice language arts and mathematics skills as assigned by the teacher (Duffield & McFarlane, 1999). Schools sign up with the company to use the software in their elementary classes and have the opportunity to send the same software home, along with the Sony PlayStation so that participating students receive further opportunity to practice basic skills. Structured teacher assignments for the software lessons, individualized for students, are conducted both in school and, under the supervision of a parent, extended at home. Designed primarily for underachieving students, the Lightspan curriculum is seen a means of improving scores on standardized achievement tests by increasing time-on-task and focused practice on specific academic skills. Studies of student standardized tests scores undertaken by districts that have acquired Lightspan have often shown improvements beyond their expectations, especially for at-risk students. Critical to the successes that the company has identified are consistent and proscribed use several times throughout the week, at home and in school, for a two- to three-month period.

The Lightspan approach offers a fixed and "closed" curriculum that has the same software activities for school and home whereas the Software Design approach tries to make homework generative where individual students continue software development started at school as homework, and start new projects that can be continued in school. This Lightspan approach and its curriculum seem to work best for those with the lowest performance on achievement tests and offer the flexibility that traditional integrated learning systems that can be used only in school lack. Further, the approach calls for parental supervision and engagement with the student which, while far from universally practiced, can provide increased motivation and the assurance that the home assignment is being accomplished.

Computer Intended for Use in Both Home and School

A third model for educational computing in the home is rare at present, but will likely become increasingly prevalent in the future with the introduction of less expensive and more durable laptop computers. In this model, students are provided with laptop computers by the school, for use both during the school day and at home. During the school day, computer uses are similar to any in-school application of educational technology (though there are advantages to having a computer for each student). When students take the computers home, they become available both for homework and for any other use that students or families wish (though these computers frequently become the “property” of the student, and thus less available to family members in general). Some early studies were conducted in an Australian school in which students were provided with laptops to take home after school. Evaluations found positive benefits in terms of students’ general and work attitude (Downes, 1995; Kessell, 1999; Shears, 1995). Another example of this model is represented by Project PULSE (McMillan & Honey, 1992), which was directed at curriculum in English and science. Outcomes included increased student and teacher motivation, and an increase in technological competence. Writing scores for students indicated marked improvement in vocabulary, persuasiveness, and organization.

A more recent example is a laptop project supported by Microsoft and Toshiba, which focused on students having fulltime computer access and general office productivity tools to support their class work and homework (Rockman et al., 1998b). Based on the earlier Australian program, each student in a class or a grade level or an entire school acquires a laptop with office productivity tools loaded on it. The model calls for the student’s family to pay part or all of the costs to acquire the computer (often heavily subsidized by the school or school foundation for those who cannot afford it), a factor that transfers the benefits and responsibilities of ownership to the students. From the teacher’s perspective, the computer becomes another tool to use in the classroom. Because every student has the computer available to them for the entire school day and all the time outside of school, teachers can make assumptions about access and capabilities, and parents have higher expectations about use. The research has shown that students used the computers during the school day at various times to accomplish a variety of classroom tasks, and used their computer as much in a school day as a comparison group with above-average in-school access did during a school week. These high-access laptop users had greater computer skills, often restructured the way they accomplished schoolwork to take advantage of their computer, and demonstrated improved problem-solving skills on simulated school projects. Moreover, the laptop computer was seen as a “school tool” and was used at home to accomplish schoolwork to a much greater degree than was the case for similar students who also had a computer at home but were not part of the laptop class. Ubiquitous access of a school tool appears to redefine the computer for many students. Their laptop is to accomplish schoolwork rather than play games, participate in Internet chats, or explore web sites. In addition, teachers take advantage of the tools by assigning more project-based instructional tasks that engage student in research, collaborative activities, writing and classroom presentations.

These efforts to provide full time access to technology indicate that students who have professional tools use those tools productively to accomplish the work of school. More importantly, the tools provide students with the opportunity to extend the school day, to conduct the work of school at home. Possessing computer tools, just as professionals would, provides both an academic advantage as well as a boost to self-esteem. The technology appears to blend into the background because it is so accessible, and the task takes the forefront. As the professional-level laptops become less expensive, more schools are planning to adopt the laptop program because of apparent benefits for both students and teachers.

ISSUES AND CHALLENGES FOR EDUCATIONAL COMPUTING AT HOME

Educational computing offers a range of new opportunities for learning at home, but for curriculum developers, software designers, and researchers, homes also present a raft of new challenges to successful use of technology. As is the case with all educational technology, computers in the home require that certain preconditions be met in order for a valuable learning experience to take place. Of course, these conditions vary with the individual requirements and context of the activity in question. Issues of technological infrastructure, access and gender equity, and research focus and methods need to be considered and will be discussed below in more detail.

One issue that is likely to be problematic in almost all cases is the technological infrastructure required for the computer in the home. Software that students use in school may not be compatible with software acquired for use at home, and vice versa. Schools face compatibility problems with competing computer platforms (e.g., Macintosh and Windows), and these problems are also present when transporting work between home and school. Furthermore, technical support is frequently required for advanced computer applications, and parents and others may not be knowledgeable about how to trouble-shoot computers or decode complicated interfaces. Researchers have recently developed sets of design guidelines to make software more "learner centered" (Soloway, Guzdial, & Hay, 1994), and this is an even more salient requirement for computing in the home. The World Wide Web (WWW or Web), with its HTML and Java standards, do offer some hope in this area.

Another infrastructure issue has to do with access to the Internet. High speed access in homes is rare (and relatively expensive where available), but for some communities, *any* access is problematic. The Buddy Project found that it had to provide outgoing-only phone lines to many families in rural areas, and nearly 20% of families participating in the NetTV Project did not have phone service. This is sometimes for economic reasons, other times for social reasons. In any event, recent statistics show that a telecommunications gap still exists in the US, with families in central cities and rural settings having the least access to regular telecommunications services (NTIA, 1998).

The equity implications of computing in the home are particularly problematic. It can be argued that home computing already enhances socio-economic inequities in access to education, and creating school-sponsored programs to support home computing makes those problems worse—the rich get richer. Initiatives to provide home computers for children who do not already have them can help to balance the obvious problem of unequal access. At this stage in the program, the Buddy Project is serving as an equity effort, since many families in participating schools already have a computer that meets the program requirements and do not get one from the school. However, simply providing equipment does not counter the radically different levels of parental support for learning in the home. While this problem already exists for traditional homework, it is especially thorny for home computing, because parents of higher socio-economic status and with more education are more likely to have the technological skill to support their children's home computing efforts. To adequately address the equity issue, programs providing home equipment must also provide solid support for its use. The Buddy Project, for instance, has extensive parent training on technology, beginning the day the computers are distributed. Parent user-groups are also common for many of the Buddy Project sites. In one large-scale Buddy Project, the public library became a central training and support site for parents with funding from the school district. For economically-distressed families, the home computer provided to their children becomes a means of job skill development for parents. Community centers may become another area in which people can get access to computer technologies outside of school, but to date the work done by students in these centers has had little or no formal linkage to the school curriculum (Zhao, Mishra, & Girod, 2000; Resnick & Rusk, 1996).

A less obvious equity problem is discrimination by gender and age. Classroom studies have reported that where computing resources are limited, boys tend to get significantly more computer time (Kaiser Family Foundation, 1999; Lockheed, 1985; Rockman & Sloan, 1995; Sutton, 1991). The same problem occurs in the home. Where one computer is shared by multiple siblings, girls and younger children may have disproportionately less access. A nine-year-old girl participating in the MOOSE Crossing program reported that she strongly preferred logging on from her after-school program to logging on from home. At home, her twelve-year-old sister would pressure her to get off the computer. The younger child got proportionally much less access time, and felt pestered and pressured during that time. The girls' parents insisted that they should get equal time, but in reality access was a constant struggle for the younger child. Even in this upper-middle-class home with highly educated parents (both with graduate degrees), access to computing time was observed to be highly unequal. Teacher-education programs prepare teachers to anticipate and prevent such access problems in school settings. Initiatives promoting computing in the home need to provide parents with similar guidance. In laptop programs, parents are informed that students' laptops are for the students' schoolwork; there have been numerous instances of parents being called to bring their child's computer to school after an adult "borrowed" it for the day.

We also need to consider the connections between education and entertainment technologies. Video games and interactive toys at home are for most children the gateway into the digital domain, often long before they start using computers in schools. Educational research has an ambivalent relationship with entertainment technologies: researchers have been struck by the motivating nature of video games; but this observation has not been translated into more extensive research efforts. While researchers have recognize the complexity and learning efforts involved in playing video games, most of the research has focused on their socio-emotional and motivational impact. Few studies have looked at academic benefits of video games (Kafai, 1995) or at the use of game features for motivating learning (Malone and Lepper, 1987). Furthermore, we note the virtual absence of any research on commercial educational software which is used quite extensively in homes and schools. Many researchers and parents have commented on the paucity of and the lack of quality in educational software in available software (Giacquinta, Bauer, & Levin, 1993).

Methodological issues in studying any form of home activity, be it computers or not, also need to be considered (Wright, 1989). Research that relies on parents' surveys of their children computer use is often unclear about whether parents report their own observations or rely on children's or their siblings' statements. Children's self-reports might vary in their judgment because of social norms and expectations. Rockman et al. (1998b) shadowed students during the school day, but relied on interviews at the beginning and end of the school day to capture planned and reported computer use for after school and at home. Even continuous home visits, as in the case of the Giacquinta, Bauer, and Levin study, which appeared to present a window into people's home computer activities are impacted by the visitor's presence and purpose. Some newer technologies such as logging software could address the accuracy issue by recording which software at what time and for what duration (if installed properly on the home computer). But with increased access to the home there are also an expanded set of ethical issues to consider (Duncan, 1996). Computers in schools, libraries, or after school programs are placed in public spaces; their educational missions are by their very nature under public scrutiny. Homes are private territory and any researcher needs to carefully balance the costs of privacy invasion with the need for data collection and reporting.

CONCLUSION

We began this article by pointing out the noticeable absence of research on the impact of home computers in the study of educational technologies in light of the constantly increasing presence of computers in children's homes. Surveys for commercial purposes indicate that parents are purchasing computers, software, and Internet connections to provide their children with an "advantage." Consequently the children from more-advantaged circumstances gain even more access at home than in school. Those from less-advantaged homes are becoming a technological underclass according to some (NTIA, 1998). Our review intended to provide models of the many potential connections and issues in educational computing at home that are currently under consideration and study. These may be starting points for more equitable approaches to larger educational and societal concerns.

Some may believe that inexpensive computing devices will provide ubiquitous access for all students, at home and in school. But as researchers and policy leaders have regularly noted, access by itself is insufficient to produce improved learning and greater success in postsecondary endeavors, nor will it be enough to produce improved learning outcomes among students who are under-achieving or under-served in traditional school settings. This article focused on different technology arrangements and parameters, yet we recognized (as previous researchers did) that computers alone are not the central factor in making educational computing at home and its connection to school work. Any effort needs to consider not only activities and resources in schools but also families and their available resources both at home and in their communities. Moll and others have described resources for learning in the home as "funds of knowledge" (Moll, Amanti, Neff, & Gonzales, 1992). These resources become available to the school in the same way that school activities and resources become available to the home. The bridge built by the network and technology can be a two-way thoroughfare, but the designers of both the technology and the activities carried out using the technology must actively pursue ways to facilitate this. We must recognize the technology-based home-school connection as an important research concern for studying equity and school achievement.

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