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ABSTRACT

A perspective about sex differences in relation to learning about computers which emphasizes the need to consider the context of societal beliefs and conditions is presented, as well as an analysis of the ways in which technology is viewed that have implications for how it is incorporated into educational settings. It is argued that, in addition to the inequity of access to computer hardware, girls and young women are often not given appropriate support and contexts for learning about this technology. Three lines of converging arguments are examined that relate to (1) the common identification of computers with mathematics and science; (2) concern about sex-related differences in science and mathematics, which also emerge in the area of computers; and (3) studies of children's learning processes and computer use in education, which provide material about patterns of sex differences in learning with computers. It is suggested that the type of use and the organization of the use setting are major determinants of boys' and girls' involvement with computers. A 33-item reference list is included. (LMM)

CENTER FOR CHILDREN AND TECHNOLOGY

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COMPUTERS AND GIRLS: RETHINKING THE ISSUES*,**

Jan Hawkins

Introduction

> Interviewer: What was the reaction from people when you became interested in math and then later computer science?
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> Nancy: Well, my math professor thought it was great, of course. My parents didn't think it was such a great idea. As far as my career was concerned, my father did not like the idea too much. He did not think it was a good field for a woman to be in.
>
> Interviewer: Did he say why?
>
> Nancy: Well he considered computer science to be very engineering-like, I don't know why really. Maybe too hard, and maybe because it wasn't English. And maybe also 'cause he thought my chances of getting a job would not be too good. My mother never understands what I'm doing. She doesn't understand computers at all.

The issue of equity of access to and learning about computers has become an important topic in education. It is a common concern that all children have equal opportunity and appropriate support for acquiring competence with the technology. These concerns derive from (1) the belief that, because many careers will require competence with computers, knowledge of information technology will be a source of power in the future; and (2) the fact that currently there are differences among groups of people in their access to bodies of

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information which may be exacerbated by unequal opportunities for learning about technology. Two important dimensions of difference are social class and sex. With respect to the latter--if current projections are accurate--girls are likely to learn less about and have less ability to control this increasingly important cultural tool.

This paper presents a perspective about sex differences in relation to learning about computers, and then attempts to analyze the ways in which technology is thought about that have implications for how it is incorporated into educational settings. It will be argued that, in addition to the problem of equity of access to the hardware, girls and young women are often not given appropriate support and contexts for learning about the technology.

Three lines of converging arguments will be examined. First, we will consider the fact that computers are commonly identified with the domains of mathematics and science. This categorization has tacit implications for how they are incorporated into educational settings and, more broadly, into functions in our society.

Second, for a number of years there has been widespread concern about sex-related learning differences in science and mathematics, and it is not surprising to find these differences emerging in the area of computers. A large body of research investigating these problems for science and mathematics has taken into consideration attitudes, interest and achievement, career statistics, and analyses of the social processes of classrooms. A number of programs have been developed to ameliorate the problems. Our ways of understanding and addressing these problems will be considered as an analogue to our thinking about current technological issues.

Third, we have conducted a number of studies at the Center for Children and Technology concerning the processes of children's learning and the use of computers in education. These studies provide us with an interesting body of material about patterns of sex differences in learning with computers. Our findings, and those reported by others, will be reviewed in light of the perspective developed here.

<u>Computers as Topics and as Tools</u>

Interest and achievement in the areas of science, mathematics, and technology have been repeatedly demonstrated to be linked to sex in educational and work environments. As computers--common exemplars of technology--continue to play an ever-expanding role in people's lives, their conceptual bonding with the topic areas of mathematics and science has important educational implications.

While computers are used for many other purposes, their computational properties as applied to science and engineering problems are especially salient. Interviews with 8- to 12-year-old children indicate that their understanding of computers emphasizes the role of these machines in science and math tasks (Mawby, Clement, Pea & Hawkins, 1984). Additionally, computers are commonly thought of as "built" from mathematical elements and concepts. This leads to the inference that in order to work with computers, people must be mathematically inclined or have prior math skills--an inference that may not be accurate. The relationship among skills in these domains is currently being tested in a research program investigating the prerequisites and cognitive consequences of programming experience for children (Kurland & Pea, 1983).

The designation of computers as a curriculum topic, and their prominent membership in the math/science category, leads to a particular kind of treatment in educational settings. As documented by Sheingold et al. (1983), schools often acquire hardware with very little idea of how it will be used. Because the larger cultural framework plays a major role in determining their placement, computers are initially incorporated into math or science curricula (e.g., Saunders, 1978), and computer science is often taught in the math department. On the other hand, some schools define computer literacy as a new curriculum area, in which the teaching of programming skills is frequently dominant.

This treatment of computers as a topic subsumed under science/math/technology has serious educational consequences for girls. Because they are most often linked with an area that has long been dominated by males, computers typically enter the classroom with an aura of sex-related inequities that has an impact on both learners and teachers.

Another way of thinking about how to incorporate computers into educational environments is to view them as tools that can be adapted to a wide variety of purposes in all subject areas--language, art, music, information gathering, and organizing--in addition to their time-honored use in math, science, and technology (Sheingold, Hawkins & Kurland, 1983). This conception of the computer as a universal, symbolic machine that can aid in the acquisition of knowledge in a number of areas can serve to broaden its category membership. The interpretation of the technology for educational settings is central to how women and girls assess its relevance to their own learning.

Women in Science and Mathematics

A number of studies now documenting sex differences in the use of computers find that boys tend to be more interested in and use the equipment more than girls (Hess & Miura, 1983; Lockheed, 1983), particularly for such functions as programming (Becker, 1982). As has been the case with mathematics (Burton, 1979; Minuchin & Shapiro, 1983; Oser, 1979), parents tend to be more supportive of boys' learning in this area than girls' (Miura & Hess, 1984). Examination of the wealth of literature analyzing sex differences in the areas of science and math offers a perspective on the assumptions that underlie these differences for computers. It is important to look at these differences in the context of societal beliefs and social conditions, as well as the factors that appear to mediate their developmental course, particularly in educational settings.

History of Sex Differences in Math and Science

There is a long history of reported differences between boys and girls in interest and achievement in mathematics, science, and related disciplines. A discussion written in 1965, for example, makes very similar points to two written in 1970 and 1983, respectively:

> Secretary of Labor Willard Wirtz has expressed concern.... "It is essential that the nation adopt a more favorable attitude toward the presence of women in many traditionally male-dominated professions"....The image, which dooms the woman [for example] engineer to a lonely and intellectual life, supposes her to be mannish, aggressive, frustrated and unpopular. It lives on, even though the field has changed ....It has been "in" for a girl to reject and suppress a talent for math. It isn't feminine. Her parents believe that, perhaps, and so do her friends. And so she believes it, too, unless she is something of an independent thinker. (Peden, 1965)

> Various of my friends are, as I am, women in science. Although our professional lives have not run the straight course of our husbands', mostly scientists as well, our work has not suffered from any prolonged disruptions. Yet each time we meet, our men mostly talk science while we usually linger on the subject of "women in science." What has gone wrong?....If success in science requires an almost straight life course from which few deviations can be permitted, the woman should be judged not after the damage has been done, from the point of view of the prejudiced male, but rather one should ask: How, if at all within our present social organization, can we create conditions under which numbers of women may make outstanding contributions to science? (Yevick, 1970)

> In recent years, underrepresentation in enrollments in mathematics courses by females and minorities has started to receive considerable attention. For example, in 1979 NCTM established a task force on "Problems in the Mathematics Education of Girls and Young Women"....In view of the increasing importance of mathematics for keeping student options open for higher education and careers, this attention to equity issues is timely. (Taylor, 1983)

Thus, we can see a history of concern on the part of educators with the fact that girls are significantly less likely to be actively engaged with these topics, both in school and in later careers. This state of affairs rests on an assumption, largely shared by many children, parents, and teachers, that these areas are not "appropriate" for girls. Burton (1979), Brush (1980), and Taylor (1983) provide statistical evidence of differential enrollment and interest in mathematics courses by sex at high school and college levels. What is the reason for this?

Historically, careers in science and mathematics have been dominated by men (Burton, 1979; Fennema, 1980). While some women have chosen these careers, they often view themselves as unusual and are so perceived by others; they follow career paths that often require them to make difficult choices about their life goals (Peden, 1965; Yevick, 1970). Girls have limited contact with career models in these areas, both in their educational environment where science and math teaching are often dominated by men (Minuchin & Shapiro, 1983), and in the general culture where relatively few women choose such careers (Brush, 1980; Kreinberg, 1980; Simpson, 1980). Young women are explicitly and implicitly told that the long and dedicated hours and intense competition associated with these professions may conflict with the traditional feminine goals of family and children. Thus, girls may be unmotivated to pursue these subjects in school because they are not understood to be relevant to their later lives (Brush, 1980). There is considerable evidence that sex differences are robust for reported interest in these areas and perceived appropriateness for men and women (e.g., Emmerich & Shepard, 1982; Entwisle & Baker, 1983; Stein & Smithells, 1969).

Development of Differential Interest and Achievement

In order to understand those experiences of children that support differential interest and achievement, a number of studies have been conducted. These studies have asked several questions, the first and most logical being: Is there is a biological basis for reported differences in abilities. Research has indicated that there may be sex-linked differences in some types of mathematical ability, indexed by spatial reasoning tasks (Maccoby & Jacklin, 1974). In addition, in-utero levels of the male hormone testerone may influence the development of genius-level mathematical ability in a small percentage of the population, as evidenced by a study correlating high-level math ability with characteristics known to be related to excess testerone during fetal life (Kolata, 1983). However, a biological explanation does not fully account for observed differences in math interest and achievement in the general population of boys and girls (Hess & Miura, 1983).

A second, and perhaps more important, question is whether the nature of the tasks posed in mathematics learning supports the engagement of boys as opposed to girls. A number of studies indicate that particular characteristics of children's learning tasks may be an important factor in the development of sex differences. For example, Licht and Dweck (1982) suggest that achievement orientations may be different for the two sexes in various subject areas. Girls and boys interpret failure feedback differently: girls are more likely to attribute difficulty in solving problems to their own lack of ability, whereas boys are more likely to attribute failure to other situational factors. Math tasks are commonly organized in such a way that the occurrence and salience of failure is greater than for verbal tasks (cf. Brush, 1980). That is, the solution of a math problem is either correct or incorrect, and the correct solution of problems illustrating a new math concept is often preceded by a series of failures. In contrast, many verbal tasks are interpretive (e.g., writing an essay) and therefore subject to more flexible evaluation which, in turn, may lead to further development of the ideas expressed. Frequent encounters with failure in math tasks may thus be interpreted differently by girls and boys with respect to their self-assessed abilities.

Lenney (1977) offers considerable support for the argument that men and women react to achievement situations differently. Her analysis of adult performances indicates that women's self-confidence seems to be affected by specific task characteristics, the kind and quality of feedback offered, and the degree to which competition and evaluation play a part. For example, she presents evidence that women are more likely to express confidence in tasks that feature social as opposed to intellectual skills. Women also appear to be less confident than men in situations where there is little or ambiguous feedback. She concludes that, as a general attribute, women may be no less confident of their ability to achieve than are men, but they may be more sensitive to particular characteristics of an achievement situation in assessing their own competence.

Parsons, Kaczala and Muce (1982) were interested in understanding what social processes in classrooms might give rise to differential feedback for boys and girls and, thus, to differential expectations and self-confidence in math. Classrooms were observed to determine the amount and kind of feedback given by teachers to high and low math-achieving boys and girls. They found that children have equivalent achievement expectations when praise and criticism are equally distributed across sex and teacher-expectancy groups. However, the social processes in classrooms can influence children's expectations for themselves: girls have lower expectations for their own performance in classrooms where they are treated differently from boys.

A third question is whether particular aspects of the larger culture (media, parents, school authorities) give different messages to boys and girls about gender-appropriate interests. A brief examination of advertising in technological areas reveals that it is overwhelmingly male-oriented. For example, one magazine advertisement for office software depicts a group of men standing around a computer, engrossed in solving a problem. A woman sits polishing her fingernails in front of the machine, clearly uninvolved, while awaiting their conclusions. The majority of advertising for products and jobs in the area of computer technology is directed toward a male audience.

Starting with kindergarten, the process of schooling is one that sorts children according to the abilities considered to be important, and by interests which the educational experience helps to define. "Who am I in the criteria of this school system, and what is it appropriate for me to do?" This sorting happens in both obvious (tests, tracking systems) and subtle (instructional feedback, interaction with teachers and peers) ways. From a very early age, children are made aware that choices and performance are going to determine both the quality of their experience in school and their subsequent career choices (Minuchin & Shapiro, 1983). Such sorting processes undoubtedly give differential messages to boys and girls about the appropriateness of their participation in different areas. This process is documented by an ethnographic examination of the sorting that occurred over the course of one year in a junior high school:

> Two girls, Charlotte and Margot, were talking with Mrs. G, the art teacher. Charlotte said the math class was really hard for her. It worried her that she was having problems because she comes from a family of teachers and she really feels the pressure is on her to do well in school....Then Charlotte remarked, "It will really hurt me to be a 'C' student in math because I want to go into architecture and the math will cut me right down." Mrs. G. responded by telling Charlotte that she has so many other talents and she

should concentrate on using them to her advantage. She suggested the art field. Charlotte: "Yeah, maybe I ought to think about going into something like textile design." (Goldman, 1982, p. 13)

Thus, both the larger culture and the culture of the school are continually providing boys and girls with information about their abilities (by which they are sorted and resorted) and about the future they can expect, based on the kinds of abilities they exhibit in the interpretive context constructed by adults.

In summary, it is likely that all of the above factors play some role in the differential interest and achievement of boys and girls in the area of mathematics. The complex nature of the environment supporting these differences makes this an intractable problem and one not easily addressed by a single type of program. A number of societal messages support the inference that interest in these areas is unusual for girls, and may present life conflicts if selected as a career choice. The organization of tasks in schools, and the social processes of classrooms appear to further support sex differences in "ownership" of and expectations about one's ability in science and math.

Educational Programs

A variety of educational programs have been developed in recent years to address the inequities between boys and girls in mathematics and science achievement. Many of these programs focus on helping girls to consider mathematics/science as future career choices by presenting them with role models of women scientists and mathematicians (e.g., Simpson, 1978; Project EQUALS at the Lawrence Hall of Science, Berkeley). The students are told about interesting careers in these fields, and are shown how preparation in school can help them to realize these goals. Similarly, teachers in various curriculum areas are made aware of the relevance of math and science to girls' future lives (e.g., Kreinberg, 1981). In this way, the programs present mathematics or science as general curriculum topics that are important for girls' futures, rather than as diverse and interesting tools for accomplishing goals in their present lives.

Those programs that emphasize changing the self-perceptions of girls with respect to science and math as necessary skills for future careers have been recommended as the most promising (Brush, 1980), and have been demonstrated to be effective in certain school systems (e.g., Taylor 1983). But since it is often hard for young children to think so far ahead, this approach alone would appear to be inadequate. It is important to recognize that math and science are tools that children can use in their everyday lives. In many school settings, relatively little effort is made to adapt the learning environment to children's interests and orientations. Focusing attention on the possible continuities between present interests and future directions is a further step.

Brush (1980) suggests that math teachers can make classes more enjoyable for students by developing math tasks which emphasize creativity and interpretation rather than success or failure. She offers the example of a teacher who incorporates geometry skills into a project to design the layout of a room. By the same token, girls may benefit from and feel more involved with learning experiences that are relevant to their current interests and circumstances.

Patterns of Difference with Computers in Classrooms

As noted above, most of the work on sex inequities in science and mathematics discusses these issues holistically, rather than focusing on the areas, skills, applications, and circumstances that may differentially engage individuals. If we view the computer as a subject, it is likely that differential interest and achievement will be similarly analyzed in global terms. We are already seeing studies that report significant overall differences between boys and girls. The reports tend to describe the computer as a unitary topic, rather than attending to the characteristics of the particular situations where differences are found. The studies noted above (e.g., Lenney, 1977; Licht & Dweck, 1982) indicate that aspects of the work context are very important in understanding the appearance of sex differences in achievement. An examination of the pattern of sex differences in the educational use of the computer as a tool is therefore important.

In order to answer questions about learning and the use of the technology in education, the Center for Children and Technology (CCT) has conducted studies examining the different uses of computers in classrooms. These studies demonstrate patterns of sex differences. Two situational factors appear to be major determinants of the engagement of boys and girls with the technology: the function for which the computer is used, and the organization of the setting in which the children work. Several of the studies will be briefly discussed below.

<u>Survey of schools</u>. Sheingold et al. (1983) conducted an indepth survey of three geographically disparate school districts to determine how computers were being used in both elementary and secondary schools. Personnel at all levels were interviewed and classrooms were observed. At many of the locations there were clear trends indicating that boys were more likely than girls to make use of the ma-

chines. However, this pattern was related to the fact that computers were frequently used for teaching programming, mathematics, or data processing in business classes where boys were the dominant users. It was also the boys who found opportunities to use computers outside of regular class time. In contrast, the teachers in one school reported that girls' interest was aroused when they were presented with software in the form of graphics tools that allowed them to create pictures and designs. The study concluded that sex was the most obvious factor affecting differential use of the machines at all grade levels across sites. These differences tended to polarize in the higher grades when students entered the departmental system where computers were concentrated in the mathematics and business subject areas.

Programming. An increasingly common use of microcomputers in schools, at all levels, is for programming. A series of studies was conducted by researchers at CCT over a period of two years to investigate children's learning of the programming language Logo. These studies addressed two issues: (1) the cognitive aspects of learning to program, and whether knowledge of programming concepts would be generalized to other problem-solving situations; and (2) the social and organizational aspects of incorporating microcomputers into classroom settings (Hawkins et al, 1982). Two classrooms participated in the two-year research project (8- and 9-year-olds, and 11- and 12-year-olds). Each classroom was equipped with six microcomputers which were integrated into the learning environment. As part of the classroom schedule, all the children were assigned individual times to work at the computer; they also had the choice of using the machines before or after school and during lunch. Thus, boys and girls had equal opportunity to work with the machines over the course of the school year.

Indepth involvement with these classrooms over a protracted period allowed us to study the development of programming understanding, and the various factors influencing the incorporation of computers into educational settings. Because the findings of this work are too extensive to discuss in detail here, we will only note the results that pertain to the emergence of sex differences.

First, in order to investigate how children learn to program in Logo and how expertise in programming develops, we developed a number of measures, including: case studies of four children--two boys and two girls (regular interviews with the children, tasks to document command and concept understanding, and monitoring of ongoing work); assessment instruments to determine level of knowledge of commands and program structures; program memory tasks to indicate level of program understanding; and problem-solving tasks accompanied by indepth interviews with the most advanced students. In general, we saw a clear trend for boys to perform better than girls on all these tasks. For example, the two boys in the case-study component developed significant programming expertise over the course of the school year as revealed by their knowledge of commands and the complexity of the programs they developed. The girls showed less interest than the boys and developed less facility with Logo.

At the end of the school year, all the children were given the programming knowledge assessment, which consisted of three parts: (1) knowledge of individual programming commands (definition and use); (2) ability to write a variety of short programs to execute specified goals; and (3) ability to debug programs containing different classes of errors. (For detailed descriptions of the tasks, scoring procedures, and findings, see Pea et al., 1984.) For both age groups, boys performed considerably better on all measures of programming expertise and, in general, showed more enthusiasm for the work and spent more time programming (mean: 34 hours for boys, 22 for girls, $p<.01$).

With respect to knowledge of programming commands, the mean score for boys was 47.2, and 25.1 for girls ($p<.01$). There were also marked sex differences in program composition skills. In this part of the assessment, children were asked to write lines of code using increasingly sophisticated programming concepts. Older children were more skilled than younger children, and the boys in each age group displayed more skill than the girls. In this analysis, a child's efforts in each of seven subtasks were classified into one of three categories: (1) correct; (2) partially correct (i.e., lines of code were correct but the child failed to organize them procedurally or to return the "object" which executed the program to its starting position); and (3) wrong or no attempted solution. The younger boys wrote correct or partially correct programs in 36% of the cases, younger girls only in 6%; older boys were correct or partially correct 70% of the time, older girls only 26% of the time.

Similarly, boys displayed more programming skill in the third component of the assessment--debugging faulty programs: the mean score for younger boys was 31.1, and 19.9 for younger girls; the mean score for older boys was 48.9, and 17.4 for older girls.

As part of the study, an ethnography of each classroom was developed which included observations, regular interviews with the teachers (both males) and students, documentation of student work, and videotapes of activities. Analysis of the teacher interviews indicates that a frequently expressed concern was the noticeable sex differences in interest and accomplishment with the programming work.

Both teachers were asked to indicate which children they judged to be "the best programmers, experts"; no number was specified. After the first year, four boys were selected by the teacher as the best programmers in the younger class. The teacher of the older children also selected four boys as the most skilled members of the class.

The teacher of the younger group felt that

> Girls' involvement was highly correlated with my interest in it. There seemed to be less clearcut benefits for girls--boys wanted to control it. They acted as if it were made for them.

The teacher of the older children speculated:

> Mechanical? Math? I'm not sure. Something I did failed to connect them. The girls who didn't work at the computers were not necessarily worse in math, but school math is different from mathematical interest. They tended to be conscientious students, and take school seriously, so some did school math well but were not really interested in it.

At the end of the year, the children completed a questionnaire which, among other items, asked them to nominate two class members who were, in their judgment, "experts" in computers. Three boys were overwhelmingly selected by the older children; two boys were designated by the younger group (see Hawkins et al. [1982] for further discussion).

When the teachers assessed the first year's work of computer programming, they reported dissatisfaction with the progress of most children and expressed particular concern about the apparent sex differences. As preparation for the second year, the teachers reorganized their presentation of the material so as to better support children's learning (e.g., presenting a more structured sequence of concepts, development of project ideas). During both years, finding functional goals for their work as they learned Logo was a continuing problem for the children. Many did not have a clear understanding of how to adapt computer programming to projects in which they were interested. Over the course of the second year, the teachers tried to spend more time with the girls and to devise projects (such as programming word games) that might better accommodate their interests. At the outset, one teacher felt that girls would stay involved as long as he introduced them to and helped them to use new skills.

However, by the end of the second year, the teachers reported that they continued to see sex differences in the amount of interest in and commitment to programming tasks. They were again asked to designate which children in this second group were the "experts," and which were "good, proficient programmers" but less knowledgeable than the experts. In contrast to the first year, the teacher of the younger children indicated that four girls (one "outstanding") and two boys were experts. However, of the eleven children in this class judged to be proficient, ten were boys. Sex differences were particularly striking among the older children (11s and 12s): the teacher judged six boys and one girl to be experts, and seven boys and three girls as proficient:

> It's really incredible, it's so clear and I'm sure I contribute some to that, but I feel a lot of it is just them. They're twelve years old and they, I think, have stereotypic views of themselves, very strong stereotypic views of themselves....So it's hard, and I think that a lot of it has to do with our culture. At any rate, it's also noticeable that the boys tend to be very interested in computers and machines, and I think this year more than ever before. Any discussion about hardware was among the boys last year, but this year the discussion has been overwhelming....Certainly, in terms of percentage of how much of [the boys'] talk is about computers, let's say--compared to girls--it's astronomically high.

It is important to note that these sex differences did not appear across the board: as noted above, four girls in the second-year class developed considerable expertise. There were individual girls in each class who displayed a lot of interest, performed well, and were judged by both teachers and peers to be competent with computers. The expert girls tended to be competent in all school subjects. This overall competence was not always true of expert boys, some of whom had previously shown little interest or competence in school but who "blossomed" when they started working with computers.

Our studies examining the development of programming skill in the classrooms of relatively young children indicate robust differences between boys and girls in levels of interest and achievement. This is particularly striking in light of the teachers' sensitivity to the problem, and their efforts to include girls in the work.

In a related study concerning the development of programming expertise (Kurland & Cahir, 1984), professional adult programmers were interviewed about their backgrounds, interests, and current work modes. Included in the sample were several young women, all of whom indicated that they were considered to be "deviant" in their career choice and found themselves to be a small minority of the students pursuing computer science.

Word processing tools. Another rapidly expanding use of computers in education is word processing--computers used as tools for writing. Studies were conducted at CCT to assess available word processors and, when none was found to be adequate for children, formative research helped to inform the development of such a tool. Observational studies were done in two classrooms (10-year-olds) over the course of a school year to determine how well the tool worked for both children and teachers. It was found that boys and girls were about equally involved in the use of the word processor (Kurland, 1983). The teachers reported that the word processor seemed to invite more collaborative writing among children. There is some indication that collaboration may be a preferred work context for girls (Hawkins, 1984; Rubin, personal communication). While it is unclear whether children wrote differently as a result of experience with the word processor, it was noted that many wrote more. Use of the software did not appear to be mediated by sex.

This pattern of interest in the word-processing aspect of computers was also observed at the Lawrence Hall of Science (Linn, personal communication). In programs to teach children (10 to 16 years of age) about computers, enrollments of boys and girls were approximately equal for word-processing courses, but a majority of boys selected programming.

Mathematics and science software. Another project has been concerned with the research and development of software for use in the science and math curricula of fourth through sixth grade classrooms. Three pieces of software were developed and tested both with individual children and in classrooms (Char, Hawkins et al., 1983). The software was designed to make use of the unique and powerful features of computers, and to model ways in which the tools are actually used by adults in their work. This research is part of a larger effort--the Project in Science and Mathematics Education--to produce an integrated set of software and materials for classrooms (as well as television and videodisc). One mandate of the project is to encourage girls to develop an interest in science and math. The three pieces of software include: (1) a tool to gather data about physical phenomena (temperature, light, sound) and to display these measurements in various types of graphic formats; (2) a simulation to introduce principles of navigation and the geometry involved; and (3) a series of games designed to introduce children to programming concepts in Logo. Since these programs fit into the existing math/science curricula of elementary classrooms, the pattern of findings concerning girls' participation is especially interesting.

Each piece of software was tested for a month in four different elementary classrooms with both male and female teachers. The classrooms were selected to represent different geographical locations and socioeconomic groups. We were interested not only in determining individual children's conceptual understanding, but also the patterns of use in the complex learning setting of the classroom. The teachers were asked to incorporate the software into their ongoing work. During and following the month-long experiment, classrooms were observed, teachers and students were interviewed, and all participating students completed an assessment questionnaire which documented amount of use, degree of interest, and development of understanding of the major concepts and skills presented in the software.

The variations in the design of the software allowed us to see the importance of two factors in the emergence of such differences: (1) the type of software as it fit into the math/science environment (tool, simulation, game); and (2) the way in which the work was organized and put into context by the teacher.

Differences between boys and girls were most notable for one of the three pieces of software--the tool used to gather and display data. Boys tended to make more use of this software than girls, often working in groups with the girls either uninterested or watching from afar. Overall, boys reported a greater degree of interest in and used the software more frequently (52% reporting multiple uses vs. 36% for girls). Boys were also more apt to report that they liked the software a lot (58% vs. 40% of girls). However, reported appeal was also a function of what was done with the software. In one classroom where children used the software to do "experiments" of interest to them (e.g., personalized activities in which they measured their own body temperatures), 80% of both boys and girls reported that they liked the software. In other classrooms, the software was used to perform such experiments as recording the loss of heat from different volumes of water.

On the other hand, while the other two pieces of software were no less technical or mathematical, there were few apparent sex differences in their use or appeal. For example, the triangulation principles introduced in the simulation software were complex mathematical concepts. In the case of the programming games, girls were more likely to report that they liked the software (83%) than were boys (64%). The simulation program appealed equally to both sexes, and there were no appreciable differences in children's responses to the comprehension questions.

We can speculate about two features of the software that contributed to their appeal for girls. First, learning experiences with these two pieces of software tended to be collaborative enterprises. The simulation game was designed such that children were required to play cooperatively. Teachers also chose to organize the programming games as collaborative work between pairs of children. Second, the goals of the software were less explicitly scientific than was the case for the data-gathering tool. The latter was introduced as part of the science curriculum for conducting experiments using the scientific method. The experimental orientation was problematic both for the teachers, who had had little science training and were not at ease with tasks requiring scientific experimentation, and for the girls, who expressed little interest in this kind of task.

In contrast, the goals of the other two software pieces were less directly tied to the traditional math/science curricula. Math/science concepts were embedded as useful tools in achieving the goals of the games (rescuing a trapped whale, finding locations on a map). The teachers were less likely to incorporate these pieces of software directly into the math/science lessons, but rather to use them as independent learning units.

Thus, the pattern of sex differences in these studies is interesting in that the differences appear to be related to the particular use of the computer, and the way this use is organized and supported in the classroom.

Conclusion

The extensive work that has been done on the emergence of sex differences in relation to learning and achievement indicates that this is a complex and deeply rooted problem which appears to be related to many factors: the impact of societal images on girls; the expectation of different life goals for boys and girls; the structure of learning tasks; the nature of the feedback in performance situations; and the organization of the classroom setting. Investigations of sex difference typically focus on a general domain, such as math ability, where the inequalities are apparent. It is necessary, however, to look deeper--to examine the functional uses of the material in particular situations in order to understand the circumstances in which boys and girls express interest and achieve competence.

As the new technology is introduced into more and more educational settings, it is important to consider the computer as a universal symbolic machine that can be designed and used for a variety of purposes. However, in the absence of a broader perspective, computers tend to be subsumed under math or science curricula and thus take on the already existing stigma of sex differences.

In summary, since the computer can be seen as a flexible tool, attention must be paid to software design and to the organization of children's classroom experience. There are two proming avenues for realizing these goals. First, it is important that computers be used in classrooms as tools for achieving a variety of goals (e.g., word processors, music editors). There need to be opportunities for use that match the goals and interests of individual children, along with appropriate support for learning about the technology. Second, the careful design of software in the areas of math and science may enable girls to view these subjects as personally useful to them. This, of course, will require taking into account both the design of the programs and the organization of learning in the classroom.

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