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Spaces for Change: Gender and Technology Access in Collaborative Software Design

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Equitable computer collaborations in mixed-gender teams have been a pressing issue for many years. While some have argued for creating single-gender teams or girls-only computer activities, our approach was different. The current study examines a three-month software design activity in which mixed teams of girls and boys (10–12 year olds) designed and implemented multimedia astronomy resources for younger students. In this context we assessed gender differences in students' levels of access to technology and how these participation patterns changed throughout the project duration. We found through our qualitative analyses that the configuration of social, physical and cognitive "spaces" in the project environment contributed to a positive change in girls' levels of access. We discuss the implications of these results in regard to issues surrounding the development and maintenance of gender equity in computer use and further research.

KEY WORDS: Gender equity; technological fluency; learning through design.

As recent research has shown, the road toward becoming technologically literate and scientifically competent has been a "leaking pipeline" for girls and women in particular, from the elementary schools where girls feel disenfranchised in science and technology, to universities where fewer female students choose science and engineering majors (Camp, 1997). A variety of explanations have been offered for this trend, ranging from different attitudes toward computers (Shashaani, 1994) and different levels of participation in computer and science courses (Chen, 1985; Linn, 1985), to cultural and social conditions found in the respective domains (Provenzo, 1991; Sadker and Sadker, 1994) and different representations of women in media publications (Heller *et al.,* 1994). While each of these variables alone or in combination have an impact on situating girls' interactions with computers, we chose to examine girls' access to computer resources in classroom activities. With the increasing use of computers in classrooms, there remains the issue of whether all students participate equally and receive equal benefits. We were particularly interested in identifying the kinds of activities and support structures that can be used in helping girls break down barriers to technological access and expertise in mixed-gender settings.

Toward that end, we investigated students' activities and collaborations during a three-month long computer project. In this project mixed-gender teams of fifth and sixth graders used Logo Microworlds™ in their classroom to design multimedia software about their astronomy unit for use by younger children. We paid particular attention to the experiences of girls in these mixed-gender teams—their access levels to the various technologies used in the software design project at the outset, the change in technology access most girls experienced, and the factors which might have impacted these changes. In examining this last factor, we outline several support structures which emerged over the course of this project to facilitate more gender-equitable technology access. Finally, we conclude this paper with a discussion of the implica-

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tions of our findings for developing and maintaining gender equity in educational technology use.

BACKGROUND

Many girls are not receiving the same kinds of opportunities to become technologically skilled as boys are (e.g., Wellesley College Center for Research on Women, 1994). Boys develop alliances with computers largely due to their extensive out-of-school computer experiences. Boys are more likely to attend summer computer camps than girls, more boys than girls have their own computers at home, boys play more video and computer games than girls do, and boys are more likely than girls to see themselves depicted (as male main characters) in these games (Sadker and Sadker, 1994). These factors relating to amount of experience with computers have a significant effect on students' attitudes and perceptions. In a survey of high school students, boys had higher ratings than girls on all of the following: perceived competence with computers, positive attitudes toward computers, and perceived utility value of computers (Shashaani, 1994).

Gender differences also arise when boys and girls use computers in the school context. Studies have found that when computers are used during class time, boys are more likely to dominate available computer resources (Sadker and Sadker, 1984). In a study observing mixed-gender dyads of students on computers, girls' attempts to request more computer access from boys often failed (Inkpen *et al.,* 1991). Research shows that boys also are more likely to initiate and maintain control of school computers during non-classroom hours such as lunch time and before or after school (Canada and Brusca, 1991; Kinnear, 1995).

When girls have as much exposure or interactions with computers as boys do, however, gender differences in perceived competence and access tend to disappear (Linn, 1985). In learning situations in which children can work on computers at their own pace and engage with tasks according to their interests and styles, girls tend to be as proficient as boys in programming (Harel, 1991; Kafai, 1995). Giving opportunities for access thus seems to be a crucial aspect in overcoming the widespread gender differences as well as finding computational activities that appeal to both genders (Spertus, 1991). Access, however, is often hard to come by, both in activities with computers and those without.

Even when computers are not involved, putting students in mixed-gender teams for collaborative work in academic subjects can result in very different experiences for boys and girls. Research shows that gender is often a strong predictor of status in heterogeneous groups; thus, girls' contributions to group work end up being less valued than boys' (see review by Cohen, 1994). These interaction patterns sometimes have consequences for girls' ability to make the most out of collaborative work, as evidenced by subsequent knowledge assessments (Webb, 1984). Even when academic achievement is not affected by these differences in interaction, girls' self-esteem and interest in the subjects in question may suffer (Wilkinson *et al.,* 1985).

In attempting to ensure that girls will have the technological opportunities they need, some researchers and practitioners have taken the approach of providing "female only" environments. Whether this means pro-active technology intervention programs that are exclusively for girls (Martin and Heller, 1994) or forming single-gender collaborative groups in after-school computer clubs (Wood, 1996), the assumption in most cases is that girls will have a more positive experience in the absence of male computer users. While these programs represent important steps in introducing girls to technological activities, we find that eventually girls will have to learn how to negotiate access in mixed-gender settings. Our aim in this project was to find out how girls (and boys) might react to the challenge of working with computers and programming in mixed-gender groups in a classroom setting.

One issue we were particularly concerned about was how to measure and track changes in students' levels of participation and access to software design in their collaborative groups. In most previous studies of collaboration, groups of students are engaged in a single task such as solving mathematics problems, learning social studies facts, or learning computer skills in isolation from other subject matters (Johnson and Johnson, 1974; Slavin, 1983; Webb, 1984). In the learning through design environment, however, the final task of making a multimedia encyclopedia requires many different kinds of activities in order to be accomplished such as research, drawing or planning screens on paper, graphic art, and programming. An additional problem was that the design project takes three months to complete—too long a time frame for the types of microanalysis or conversational turn counting typical of short-term or laboratory-based cooperative learning studies (Barnes and Todd, 1977;

Cohen, 1982; Webb, 1984). In contrast to these methods, which examine collaborative groups engaged in short-term, isolated tasks, we were interested in documenting participation patterns on a much wider scale. The wide scale we refer to here pertains not only to issues of participation over time, but also to a broader lens on collaboration and access within different spaces in the design project classroom.

We wanted to investigate participation in the various software design tasks over the ten-week project timeline and across the whole classroom community. The task of designing software is comprised of several interrelated activities: programming, planning, content research, collaborative team management, and graphical design. Ideally, all students would participate in all activities equally; however, the fact that some of these activities are computer based (programming, graphic design), while others are not, led us to consider that gender might be a factor in students' opportunities to participate in all design components. Furthermore, as the nature of the design task changes over the course of the project (from initial planning and paper designs to computer implementation), we were also interested to see how students' participation in design would likewise change. Similar patterns of participation change have been documented in out-of-school communities (Lave and Wenger, 1991) and classrooms (Roth, 1998; Roth, 1995). These studies, however, have not focused on the important component of computer technology in the classroom—important, particularly, for issues of gender equity.

In this paper we use the metaphor of "space" to examine participation and technology access in the software design project. Here we draw on existing research which has documented how students use the physical space of their classroom while engaged in different kinds of collaborative and individual tasks (Getzels, 1974; Gump, 1974), and how the arrangement of artifacts in physical space impacts students' participation in classroom activities (Roth, 1995; Roth and Bowen, 1995). Other studies on spaces in design have looked at externalized creative spaces in architecture, such as computer-aided design programs or pencil and paper designs, and examined participant interactions around each (Hall and Stevens, 1995; Schon, 1988). In our analysis, we were interested in some similar issues: how boys and girls arranged themselves in different workspaces in the physical layout of the classroom, and how students used paper or computer-based spaces to display designs in-progress. Unlike previous studies, however, we have extended the notion of space to focus not only on artifacts and the physical environment, but we also use "space" as a metaphor to integrate more intangible components of the design environment, such as student social interactions and individual or shared understandings of design plans, into our analysis. It is this integration of multiple perspectives on the design environment, plus our focus on long-term participation patterns for boys and girls, that fuel the story we have to tell.

METHODS

Research Participants

An integrated class of 26 fifth and sixth grade students participated in this project. There were 10 girls and 16 boys of mixed ethnic background (19 Caucasian; two Hispanic; three African-American; three Asian) ranging between 10 and 12 years of age. Nine students either participated in another design project the previous year (n = 8) or knew programming from home (n = 1), and 17 students had no programming experience before the start of the project. All the students had used computers in school and were familiar with word-processing packages, graphics software, Grolier's Multimedia Encyclopedia™, and searches on the World-Wide Web.

Heterogeneous groups of three to four students each were arranged in seven teams according to the following criteria: "experienced" designers who had participated in a previous design project, gender, grade level, and classroom leadership (as indicated by the classroom teacher). Six of these experienced students were boys and three were girls. Students received colored cards representing their particular research criteria and were told to form groups having not more than two of each color. Some students represented more than one category, so groups could not be completely matched across all variables; however, all groups contained a mix of all criteria (Table I). Our primary goal, in addition to creating mixed-gender teams, was to balance the levels of existing technological knowledge across the groups, so that each collaborative team would contain at least one student who had done some programming previously.

Classroom Context

The software project from which our gender study comes is based on the model of "learning

Table I. Composition of all Groups

Group 1	Group 2	Group 3	Group 4
5th grade girl	5th grade girl	5th grade girl	5th grade boy
5th grade boy	5th grade boy	6th grade girl (exp.)	5th grade boy
6th grade boy (lead/exp.)	6th grade boy (lead/exp.)	6th grade boy (lead)	6th grade girl (exp.)
		6th grade boy	6th grade boy (lead/exp.)

Group 5	Group 6	Group 7
5th grade girl	5th grade girl	5th grade girl
5th grade girl (lead)	5th grade boy	5th grade boy
5th grade boy	6th grade girl (lead/exp.)	6th grade boy
6th grade boy (exp.)	6th grade boy (exp.)	6th grade boy (lead/exp.)

through design,'' in which students simultaneously learn new information and design a relevant product reflecting their knowledge (Harel, 1991; Harel and Papert, 1991; Kafai, 1995). The project took place in an urban elementary school that functions as the laboratory school site for UCLA. The participating classroom was equipped with seven computers; one was set up as a workstation at each of seven table clusters. An additional seven computers were in an adjacent room and were used for related Internet searches.

One week before the start of the project, students were given an introduction into the main features of the Microworlds™ Logo programming environment. The assignment was to build an interactive multimedia resource about astronomy for younger students. Over the course of several months students created their own research questions about astronomy, researched these questions using various sources, and represented their findings in a group software product. Students worked three to four hours per week on the project for a period of 10 weeks. Students spent a total of 46 hours in the learning by design environment, of which 23 hours were dedicated to independent work researching and creating screens in Microworlds representing the astronomy information they had learned. The other 23 hours were spent in whole-class activities: science instruction, class discussions about science issues and project logistics, and group presentations.

Measuring Student Participation

Collaborative groups were videotaped regularly, and their activities were documented via fieldnotes on a daily basis. Student teams also kept daily reports of their progress in three-ring binders. Each day someone in the group was asked to write down in the ''design folder'' what each team member had accomplished during that class period. Development of a coding scheme measuring boys' and girls' levels of participation and access in their collaborative teams was based on ethnographic observations (described below).

Creating the Scheme. We set out to document the developing classroom community and track students' access to the activities comprising the practice of software design. While in professional software design groups, individual activities such as coding or graphical design are usually handled by specifically designated and trained people, in educational software design groups, all students were expected to participate in all activities for their learning benefits. We recognized that although various activities in the classroom environment were all necessary for astronomy research and working on the multimedia encyclopedia, these activities afforded very different levels of access to one of the design project goals, one which is particularly important for girls: technological fluency. We were interested in what affordances these project activities had for the following technological fluency goals: (a) that students have access to actually designing and implementing screens in multimedia design, not just thinking about how to implement them; (b) that students experience using computers not only as consumers of software but also as producers; and (c) that students use computational media in conjunction with traditional media such as paper-and-pencil.

In addition to our own concerns about activities' affordances for fluency development, we found that students themselves had very definite opinions about which activities they preferred. Through observations of student arguments at the beginning of each class over whose turn it was for certain tasks and through discussions with students about access or lack thereof to particular technologies, it became obvious to us that students viewed certain activities in the design environment as being more desirable than others. Below are two examples of student arguments, transcribed directly from videotapes of group interactions, demonstrating the perceived difference in value of working in Microworlds at the computer versus either (a) recording the group's daily progress or (b) researching one's individual astronomy question. The first segment shown takes place between a boy (Mel[4]) and a girl (Christa). The second segment occurred between two boys, Joey and Lyle.

(a) Recording vs. programming:

Christa: Who's recorder today? Is Fredo recorder today?
Mel: It's Fredo two times, then me two times, then Elaine-
Christa: Oh, I'm recorder tomorrow.
Mel: No, you're LAST, so you're it *today. I'm* programming today.
Christa: But I'm after Elaine.
Mel: Right. I just said-
Christa: Okay, fine.

(b) Researching vs. programming:

Lyle: Joey, I have to finish my page.
Joey: Okay, I have to make the thing about the earth and the moon.
Lyle: Actually you should research on comets. 'Cause that's your question. Your question isn't, like, 'how the moon goes around the earth.' It's 'why comets have tails.'
Joey: That's not what I'm doing right now.
Lyle: But you have to research on comets' tails!
Joey: I know!
Lyle: Well, do that today. 'Cause you haven't been doing it very much.
Joey: I'm just pasting this on, so we have a page for all the planets.
Lyle: No, do it today!

Interestingly, student preferences quite often overlapped with our own opinions about which activities would aid more technological fluency development. We classified all the activities we saw students doing on a daily basis according to their affordances for access to the goals outlined above. Activities which used only traditional paper and pencil were viewed as having very little affordance for developing or enriching students' fluency with new technology. Another category was comprised of activities which used computer technology, but only that with which students were already familiar. Thus participation in those activities was viewed as having affordances for maintaining a constant level of students' technological fluency, but not for challenging them to develop new skills. Finally, the activities in the third category involved students working with computers in ways many had not encountered before, thus enriching their development of greater technological fluency.

It occurred to us that 'desirability' according to the students was related to two facets of the access afforded by the various activities. One aspect of this classification is that the undesirably perceived activities are also "low-tech." As activities increase in desirability, they afford more access to computer technology, whether it be consumer applications or creative tools such as Microworlds. The second aspect of the classification which seemed to resonate with students was the access afforded by particular activities to "locally novel" resources. Microworlds programming and the Internet were the newest components of the classroom environment. They had been added only a few weeks before the start of the project. The other options, books, Grolier's Multimedia Encyclopedia, Word Processing, worksheets, etc., were very familiar to students already. We used this classification to code students' participation patterns in the various activities available for their astronomy software design.

Using the Scheme. In order to document changes in access over time, we selected two time points in the project: one was the third full week of Microworlds work, and one was the eighth week of Microworlds work. (Recall that the students were engaged in making their multimedia encyclopedias for a total of 10 weeks.) We determined that a whole week at each time point was needed for coding rather than only one or two days due to a concern for having all students represented multiple times at each data point. We wanted to record students' typical activities during those two phases of the project, not just to document their activities on a single day, which may or may not have been reflective of their usual participation.

To integrate the various forms of data that were collected during those two weeks, we looked at all fieldnotes, videotapes, and team design folders[5] for

[4]All names have been changed.

[5]Folders were reliable as a means of documenting when particular team members performed the activity of completing the daily report; however, these folders were not reliable as a means of documenting a variety of student activities on a daily basis. This was largely due to the fact that many recorders filled out the progress reports at the beginning of class rather than at the end. Reports thus stated what team members were *supposed* to do that day, but recorders often did not update the reports to reflect what actually happened.

Table II. Classification of Activities

Enriching activities	Constancy activities	Traditional activities
Microworlds programming	Grolier's Encyclopedia research	Book corner research
Internet research	Isaac Asimov CDs research	Drawing screens on paper
Leading group demos	Word processing	Team progress reports
Teaching others to program	Watching others program	

each day during those times and created two case files for each group: one file for ''Week 3'' and another for ''Week 8.'' The case files included each student's name and the activities he or she was observed to be doing. A group member received an activity code when he or she was engaged a particular task for most of a given class period. Sporadic activity, such as watching someone program for only a few minutes, was not counted. In this way the most codes one person could get on a given day would be two, spending roughly half the period on one task and half on another. For example, during the whole eighth week, Joey (a sixth grade boy) was documented creating screens in Microworlds three times, researching with the Isaac Asimov CD set once, researching comets in a book once, and watching another group member program twice.

These case files were then coded according to the classification in Table II. Tallies were created of how many times each student was observed participating in all three categories of design activities at each of two time points. These scores were then used for further analysis of change in students' access to the practice of software design.

RESULTS

In our presentation of results, we discuss first the outcome of descriptive analyses examining boys' and girls' levels of participation at ''Week 3'' and ''Week 8'' in project activities with varying affordances for developing technological fluency. Second, we present qualitative findings on trends in boys' and girls' participation patterns throughout the project duration, as seen through the metaphor of different ''spaces'' within the design environment. This second take on our results not only represents another perspective, but also offers some rationale for why and how participation changes took place.

Gender and Access: Coding Results

If we examine the mean number of times boys and girls were engaged in the different categories of technological activities at ''Week 3'' and ''Week 8,'' we can see some interesting trends (see Table III). At the first time point, girls' average participation in traditional activities was twice as frequent as boys', and they were performing less fluency-enriching activities than boys; however, boys' and girls' participation in technological constancy activities was fairly equitable. By the eighth week, the differences between boys and girls on traditional and enriching activities appear to even out. Additionally, the frequency of participation in constancy activities decreases across the board for boys and girls. These results seem to suggest that constancy activities somehow became obsolete or less popular for all students as the project progressed. If we consider that three of the constancy activities; word processing, Grolier's research, and Asimov CD research all have to do with obtaining information about research questions and writing up that information in students' own words in order to design their simulations, these results make sense. Most students conducted their research during the first half of the project and spent the remaining time planning and implementing their designs and/or helping others. The change in participation we see in constancy activities, then, was most likely affected by order of events in the project progression and not gender or other collaborative dynamics.

As displayed in the differences in mean levels of activity in the table above, girls did appear to move from more traditional activities at week three to activities affording more technological fluency at ''Week 8.'' The sort of changes that took place across the classroom as a whole suggest that gender played an

Table III. Mean Participation in Project Activities by Gender

	Enriching activities	Constancy activities	Traditional activities
Week 3			
Boys	2.812	1.437	1.437
Girls	1.200	1.800	2.900
Week 8			
Boys	2.000	0.687	1.500
Girls	1.900	0.200	0.900

important role in students' initial activity participation, but that these gender differences did not remain constant throughout the ten weeks. There is another story to be told here, however, and that is the story of *how* these changes in participation took place. The transition from a gender-biased distribution of labor to one that was more equitable was neither easy nor spontaneous; it required significant interventions by researchers and the classroom teacher. While the absence of a control group in our design does not allow us to argue for a causal relationship between these interventions in various ''spaces'' within the classroom and subsequent changes in girls' activity patterns, our particular experience with attempting to alter significant design spaces for gender equity purposes provides an interesting chapter to the ongoing efforts to address gender and technology in the classroom. What those ''spaces'' were, how they were altered, and subsequent changes we observed will be discussed in the following sections.

Spaces for Change

Our findings for the third week, that girls were typically participating in less programming-related activities, are reflective of several phenomena: some girls actively decided not to begin programming right away and focused more on research or graphics first, others gave in to more aggressive boys in their teams who insisted on working on the computer first, and still others seemed to wander aimlessly without a clear conception of how to approach the project. None of these things were particularly surprising, given the existing literature on gender and technology.

During the fourth and fifth weeks of the design project, however, we observed that patterns of access to particular technologies, design tasks, and group decision-making during this time seemed to be remaining fairly constant, where we had anticipated that shifts would occur gradually as more girls gained skills and knowledge of software design. Fieldnotes and video from those weeks reveal several phenomena which point to incongruity between girls' readiness and/or desire to program and their levels of access: Researcher conversations with girls in which girls complained of a lack of computer access; group arguments over whose turn it was to work in Microworlds each day (see previous examples of student arguments); and software demo sessions in which girls revealed that despite having gathered research information, they did not have much Microworlds work to share due to limited programming time.

In hopes of facilitating shifts in group participation patterns, we added two features to the software design project: 1) regular group meetings mediated by the classroom teacher, and 2) a different physical configuration of computers designated for programming. We refer to the process of altering the classroom design studio as ''creating spaces'' on the social and physical planes of the environment. Within these ''spaces,'' girls (and some boys as well) found contexts which were more compatible with their own ways of interacting, working, and thinking than they had encountered in the initial structure of the design environment.

Social Space. The addition of the ''social space'' of regular group meetings was in response to specific problems we saw happening between boys and girls in their daily interactions. We witnessed girls trying to discuss interpersonal problems within teams right away when they arose, while boys focused on getting computer work finished and would keep right on working and not deal with personal conflicts. These findings are consistent with existing research which shows that when mixed-gender groups of students engage in collaborative computer work, boys' and girls' effort and interest tend to be divided in favor of technology versus group orchestration, respectively (Fredricks *et al.,* 1997). After observing boys and girls having trouble communicating for several weeks, we saw a need for a specific ''space'' on the social plane of the design project which could be an appropriate time and place to deal with conflicts in a safe and monitored environment.

Our solution was to create group meetings which were mediated by either the classroom teacher or a researcher. These meetings occurred approximately once every 10 days. Students were told that each person in the group would have a chance to say what was bothering them, and then the whole group would address each issue. We found that while we had initially instituted the sessions to ensure that girls would be listened to by boys in airing their complaints about access, boys also had many issues they needed to address. The addition of an official time to talk about group conflicts seemed to make boys more comfortable and not as worried about ''wasting'' computer time on interpersonal issues. We observed many boys open up and discuss issues they were concerned about such as Internet use for legitimate research versus ''surfing'' for fun, ownership and piracy of ideas, and accusations of ''goofing off.'' Thus, although the ''social space'' of group meeting time was initially created as a place to address girls' concerns, boys benefited from this development as well.

One of the outcomes of these meetings which seemed to have the strongest relation to girls' attainment of access to more advanced technologies was that all groups established a computer schedule. These schedules detailed who would work on Microworlds programming and research on the Internet each day. Video and fieldnotes revealed that after the first round of group meetings, girls were more often working at their groups' computers. Most boys and girls also reported to researchers during the next few weeks that there were less conflicts in their groups after the meetings.

Physical Space. Although computer schedules created in the social space of group meetings ensured that girls received equal access to the physical artifact of the computer itself, we discovered that schedules did not ensure equal participation in programming. Students saved their work in Microworlds under new file names with new dates every time they worked, so researchers could keep track of how much work was accomplished on a given day. By examining students' log files, we observed that when girls had opportunities to work at the computer workstations, they often got much less accomplished than boys did in the same amount of time. Fieldnotes and video from the classroom revealed that unlike boys' typically independent work styles, girls frequently shared their new work with friends and left their seats to view one another's screens. Group stations were spread throughout the classroom, making it difficult for students in different teams to communicate with one another without getting up and walking away from their own computers. Based on existing research which argues that segregated workstations tend not to appeal to girls and their preferences for a work style characterized by more social networking (Canada and Brusca, 1991), we hypothesized that girls' lack of productivity at the computer might be partially attributable to the ''physical space'' of the classroom workstations.

At the beginning of the project there were seven additional computers in the adjacent lab, but these were designated for Internet searches and other research only; students were supposed to program in Microworlds™ at their groups' workstations inside the classroom. During the sixth week of the project, however, four girls began ''breaking the rules'' and appropriating the laboratory computers for Microworlds™ work. These girls regularly moved files back and forth from lab computers to group workstations via file sharing or floppy disks. The physical space of the lab was such that computers were lined up in rows right next to each other along the walls rather than being spread out; we wondered if this arrangement made a difference. We were curious to see what effect this new physical space might have on more girls (and most students had finished the research phase of their work anyway), so we opened up the lab for regular Microworlds use. Changes took place almost immediately. Rather than waiting to have their activity directed by other group members, the teacher, or researchers (as was often previously the case), many girls grabbed their floppy disks and headed off to the lab on a daily basis with a long list of things they wanted to accomplish on their own.

Creating a new ''space'' on the physical plane of the design environment in which to do programming afforded boys and girls different options for how to work and help one another. Most boys worked at the isolated group workstations, which were spread out across the classroom, and would call one another over for help with specific problems. All but two girls (and a few boys), on the other hand, worked collaboratively and used the space in the adjacent computer lab. We observed these girls talking and giving programming/design advice by glancing over at one another's screens while they were all working together. This arrangement seemed to encourage those involved to stay on-task longer and develop innovative ideas to be shared with the rest of the community. These findings are consistent with existing research which shows that motivation and achievement are higher among girls in peer groups with similar mindsets and goals (Fredricks and Alfeld-Lo, 1997).

Cognitive Space. Finally, another space in the design project environment is ''cognitive space.'' The cognitive arena of the design project refers to two kinds of planning, one shared and one individual. Shared planning refers to the ways in which student teams negotiated together how they would make their multimedia software. We provided students with a space in which to make their shared plans explicit, a team notebook containing the daily reports described earlier and space for other plans. We found that the contents of these shared planning notebooks were very similar across groups. For the most part, student teams did not include anything in the way of screen designs, astronomy notes, or Logo ideas in these notebooks. In fact, they usually did not contain anything other than an archive of the teams' daily reports, and plans recorded here mostly related to division of labor and allocation of technology resources within groups. We had hoped that the group notebooks could be a place for groups to document and deal with issues of astronomy research, screen ideas, and programming hints, as well as division of labor. Interestingly, once group meetings were established, these issues were dealt with in that social space instead. Thus the most effective shared cognitive space seemed to be ''in the air'' during students' structured conversations, rather than on paper.

The individual level of planning involves the students' cognitive negotiation between their own ideas for contributions to their team's multimedia product and their conceptions of project parameters, deadlines, and available resources. The space we provided for individual planning took the form of individual ''designer's notebooks'' where students could record their ideas, plans, and progress, thus making that negotiation explicit. These notebooks were designated for individual use and were in addition to the shared team notebooks discussed above. Planning within the cognitive space of the designer's notebook did not take into account issues of access and management of limited technological resources; it was only focused on the individual designer's ideas and goals. Contents of these individual notebooks varied widely among students. Some of the kinds of planing students documented in their individual notebooks included notes from science instruction, screen designs, Logo code ideas and helpful hints, project calendars with important deadlines, and print-outs from information resources about particular astronomy topics. Other students, however, did not seem to use their individual notebooks very much. Interestingly, we found that some girls used their individual notebooks a great deal during the time when they were accumulating ideas for screens but not implementing them for whatever reason. Thus, when they obtained Microworlds access, either through negotiating turns at group workstations or programming in the lab, they drew heavily on the plans contained in the cognitive space of their individual notebooks.

DISCUSSION AND IMPLICATIONS

In our discussion of results, we want to address several issues which arise from the findings our study yielded. First, what is the significance of the ''spaces'' that were created in this project? Why were they as effective as they were? And second, what suggestions do our findings offer in terms of directions for future research? Finally, what are the implications of our findings for the ways we think about current trends in educational technology and research on gender and computers? Each of these questions will be addressed in turn in the following sections.

Negotiating ''Spaces'' in Multimedia Design

In our view, the spaces that we examined in the classroom environment are more than interventions to increase girls' access; they represent a way of conceptualizing three kinds of negotiation that go on in the process of multimedia design. In the social arena of collaborative teams, designers attempt to create shared understanding within their groups. Designers must negotiate between their own goals and ideas for the astronomy software and that of their team members, which is not an easy task. The addition of a specific space designated for conflict resolution moved this negotiation from being an implicit necessity to being an explicit goal. In the physical space of the classroom and its computer configurations, designers negotiate between their preferences and ideal working conditions, whether they be collaborative or independent, and the options afforded them by the physical environment. Adding another computer configuration allowed some girls a ''better fit'' between their apparent preferences and the available options. And finally, the cognitive space of the individual and team design notebooks allowed students to draw a line separating their planning negotiations with team members from their own individual plans for multimedia pages—a division which may have been helpful in compensating for initial gender differences in access to programming. Looking at the project environment through the lenses of cognitive, physical, and social spaces proved to be a useful exercise for thinking about activity in these arenas. We did not actually *create* the cognitive, physical, and social ''spaces'' in the design project; they were present from the outset. We merely altered the configuration of two of these spaces to allow for different ways of negotiating the terrain of software design than were afforded previously.

Directions for Future Research

One of the most important points emphasized in this study deals with accounting for how students work in collaborative groups in complex classroom environments when there is more than one activity going on at the same time. In the design project discussed here, it was important to examine all the activities students could be engaged with according to their affordances: affordances for novel technology use, affordances for fun and interest as reflected in student desirability, and affordances for access to the practice of software design. This study represents an important step in going beyond the typical computer/no-computer distinctions in gender and technology research to look at what different computer applications girls and boys were using in a multi-task environment. Our future research will take the next step and look at *how* boys and girls are using the resources they have at their disposal, not just which resources they are using. For example, it would be interesting to know what sorts of programming girls and boys are doing in Microworlds on a daily basis, not just whether or not they are using Microworlds at all. Additionally, efforts are currently underway to look at the division of labor in creating final multimedia products and the different tasks such as creating graphics, animation, sound, audio, etc. boys and girls may undertake in their groups when working with Microworlds or other software design tools.

Implications

In talking about the implications our findings have for gender and technology research, we want to return to two of the driving forces behind our investigation: 1) the shortage of women's participation in computer science and related fields and 2) the issue of girls' access to technology in classroom communities. Currently when the majority of women choosing majors upon entering college have had prior experience with computers since elementary school, it seems to us that the two phenomena may be related. Certainly they will be related in the future. The extent to which girls learn to use cutting edge technology and become participants in software design or other computer communities early in their school lives may affect their later choices.

Lave and Wenger argue that, "understanding the technology of a practice is more than learning to use tools; it is a way to connect with the history of the practice and to participate more directly in its cultural life," (1991). Girls' access to full participation in software design or other similar activities is thus important not so much because they learn isolated computer skills (which may or may not become obsolete eventually), but rather because participation affords girls a way to connect with the male-dominated practice of software design. Previous intervention models such as science and technology after-school programs and summer camps that reach out to females in high schools and colleges, while important, may be situated too late in development, considering that girls form many beliefs about themselves and their relationship to science and technology at a much younger age (Kahle and Meece, 1992). For that reason we propose to provide younger girls with opportunities to interact with advanced technologies and science in substantial ways.

A related issue is the emphasis we place on children as producers, rather than strictly consumers of computer software (Kafai, 1995). Our findings suggest that while the software industry is just now beginning to create products for girls as software consumers, the idea of girls as software *designers* may be still hard to swallow for children ages ten to twelve. The fact that gender was so strongly related to initial participation in fluency enriching (or "high tech") activities in our study is of particular interest, because it suggests that even at a young age, children's actions with respect to classroom technology are very gender biased—another argument for the early positioning of interventions mentioned above. The change in access most girls experienced, however, shows that these behavior patterns are not immutable in a supportive environment.

We need to examine new developments in education and technology and consider their implications for how we think about gender and computer use. Education is currently in the throes of a trend in project-based learning (Blumenfeld *et al.* 1991) for computers to be integrated into long-term, multifaceted projects such as the one documented here. Computers no longer reside solely in a distant laboratory with few if any ties to other classroom activities (Kafai, 1995). If girls have little access to computer resources in these integrated classroom settings, they not only miss out on the opportunity to develop technological fluency, but they also risk missing out on learning other subject matters being mediated by computer use as well. In our project, which was supposed to provide students with creative and innovative opportunities, girls' initial computer work consisted mostly of word processing and consumer-based use of software encyclopedias. But observing the initial inequality in technology access per se is not the surprising issue; given that some boys in our project had different technology experience to begin with, one would expect such differences. What is important is that these inequalities did not persist throughout the project. Organizers of technology-rich activities such as software design in classrooms need to recognize that individual students, boys and girls, may have different levels of access and interactions with technology. What is important to realize is that participation patterns can and should change as the project moves toward completion. Project-based collaborative groups have the potential to be adaptive, dynamic systems; our study demonstrates that researchers and teachers need to take an active role in helping students realize that potential.

Finally, our research provides support for the argument that we are reaching a point in gender and technology research where the issue may no longer be about *if* girls are using the computer but rather *how* are they using it. Through creating new spaces in the design environment, we were able to provide opportunities for girls to gain technology access. We argue that such measures are necessary to facilitate girls' development of their own identities as participant members not only in the classroom computer community, but also in the technological community at large.

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