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ORIGINAL ARTICLE

Social Interaction During Computer-based Activities: Comparisons by Number of Sessions, Gender, School-level, Gender Composition of the Group, and Computer-child Ratio

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Abstract This study assessed the quality of social interactions that occur in group-based computer learning contexts. Gender comparisons of interactions were examined across 3 sessions with 116 preschoolers (*M* age=4.9 years) and 108 fifth and sixth-grade (*M* age=11.7 years) Canadian children from southwestern Ontario, when children had access to one computer per child (parallel computer) or one computer per group (integrated computer), and when they worked with same-gender or mixed-gender peers. Preschoolers engaged in more collaborative behaviors in mixed-gender than same-gender groups, while elementary children engaged in collaborative behaviors more often in integrated than parallel computer conditions. In mixed-gender groups, boys were more likely than girls to dominate the computer in elementary school while girls were more likely than boys to dominate the computer in preschool.

Keywords Gender comparisons · Social interaction · Computer-based activities · Preschoolers · Elementary school children

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Introduction

The increasing availability of computers and Internet access has made computer technology a fixture in elementary and secondary schools, as well as in early childhood education environments (US Census Bureau 2005). Advances in multimedia and hypertext capabilities make the computer an attractive cognitive tool for education (Mayer 2005; Willoughby and Wood 2008). In the last 20 years an abundance of observational studies in countries such as the US, New Zealand, and the UK have led researchers to suggest that computer-based learning environments facilitate social interactions among young learners (e.g., Bergin et al. 1993; Fitzpatrick and Hardman 2000b; Podmore 1991). In general, these social interactions are positive; for example, promoting active sharing and turn-taking behaviors (Muller and Perlmutter 1985). In addition, preschoolers and elementary school children working on computers tend to be less distracted, more collaborative and more persistent than when working on non-computer-based tasks (e.g., Hawkins et al. 1982; Podmore 1991). Encouraging children to work together on computer tasks, however, may not necessarily result in positive and academically relevant social interactions. For example, not all children working together may participate to the same extent, and the quality of the social interaction may vary for boys and girls depending on factors such as: (a) gender composition of the group, (b) school level, (c) computer-to-child ratio within the group, and (d) changes over time. In the present study we examined these factors to determine when and for whom small-group computer activities are most likely to foster positive social interactions.

Group Composition

Researchers have reported differences in the type of social interaction that occurs around the computer as a function of the gender composition of the group. For example, Martin (1998) in a study of Canadian elementary school children found that pairs of girls worked more collaboratively and had higher levels of interaction than pairs of boys (see also Underwood et al. 1994). Other researchers, however, have found no significant differences in performance between female and male pairs of school-aged children (Howe and Tolmie 1999; Pheasey and Underwood 1994; Sutton 1991).

When contrasts are made between same-gender and mixed gender pairings, however, researchers have reported findings that are more consistent and identify an advantage for same-gender pairings. For example, Underwood et al. (1993) found in a UK sample of elementary school children that mixed-gender groups engaged in more disagreements in comparison to same-gender groups (see also Lockheed and Harris 1984), even when the children were instructed to cooperate with one another. Furthermore, Light et al. (2000) found that elementary school girls in the US participated more actively in a computer context when in same-gender versus mixed-gender groups (see also Fitzpatrick and Hardman 1994; Underwood et al. 1994, Underwood et al. 2000). In both US and UK studies, elementary school girls also were submissive and more likely to be critiqued in mixed-gender groups than when working alone or in all-girl groups (AAUW 2000; Fitzpatrick and Hardman 2000b), while elementary school boys in mixed-gender groups monopolized the computer as well as discussions (Hooper 2003; Reis 1998; Underwood et al. 2000). Interestingly, Ausch (1994) in the US and Fitzpatrick and Hardman (2000a) in the UK found that elementary school boys' assertive behaviors in mixed-gender pairings may be more specific to computer learning situations, as elementary school girls demonstrate assertive or controlling behaviors during non-computer-based tasks when partnered with boys.

These previous studies, however, have typically involved only two children working together on a computer. Children in mixed-gender groups may not engage in as many negative interactions when the group of children is larger. For example, in groups of four children with two boys and two girls, each child would have both a same-gender group member as well as opposite-gender group members. The addition of a same-gender peer to the mixed-gender groups may compensate for the disadvantages typically found with mixed-gender groups. On the other hand, in a computer setting, boys may continue to dominate the girls in mixed-gender groups even with the addition of a same-gender peer. To examine this issue, in the present study we examined social interaction in a computer-based activity with both same-gender and mixed-gender groups of four children.

School Level

The previous studies primarily involved children ranging in age from 7 to 12 years of age. It is not clear whether these outcomes apply to younger children. Gender differences as a function of group composition may be less prevalent in very young populations, similar to the finding in both US and Canadian studies that gender segregation in play increases in prevalence from preschool to elementary school (Maccoby 1988; Serbin et al. 1993). Specifically, elementary school children find playing with peers of the opposite gender less pleasing and are likely to behave more negatively toward opposite-gender than same gender peers (Underwood et al. 2001). Maccoby (1998) suggests that gender segregation is the result of an incompatibility in play styles. Girls tend to withdraw from social interactions that include boys because they are viewed as too boisterous and dominating. It is not surprising then, that elementary school children may work better in same-gender groups (Green et al. 2003).

Young children's interactions with the opposite gender may differ from that of older children as preferences for same-gender playmates begins to develop during preschool and increases into elementary school. Indeed, although Ausch (1994) found that US girls between 5 and 6 years of age in mixed-gender dyads engaged in more aggressive behaviors than girls in same-gender groups, Langlois et al. (1973) found that among a sample of 3-year-olds in the US, boys' behaviors varied as a function of the gender of their partner whereas girls' actions were relatively unaffected. Specifically, boys engaged in more positive behavior when partnered with a girl. In contrast, Leman et al. (2005) found that elementary school boys in the UK engaged in less positive behavior in mixed-gender than same-gender groups. Furthermore, Holmes-Lonergan (2003) found that children in the US between 4 and 5 years of age in mixed-gender dyads were more likely than children in same-gender dyads to use negative controlling behaviors, but boys in the mixed-gender dyads also were more likely than girls to use verbal agreements directed at their partner. Importantly, the studies with preschoolers did not explore gender differences in social interactions during a computer-based activity. The differential outcomes found across school level, however, suggest that there may be an interaction between school level and group composition (mixed-gender versus same-gender) in the type of social interactions observed in computer-based activities. Specifically, elementary school children may be more likely to display fewer collaborative behaviors in mixed-gender versus same-gender groups while preschoolers may be more likely to display fewer collaborative behaviors in same-gender versus mixed-gender groups. In the present study we included a sample of both preschool and elementary school children to explicitly test this hypothesis.

Computer-child Ratio

Researchers may have observed increased social interaction in past studies examining computer use because of the limited number of computers typically available in the classrooms being studied (Fitzpartrick and Hardman 2000a; Lou et al. 2001; Wang and Ching 2003). In a 2005 Teachers Talk Tech survey which sampled 1,000 selected kindergarten to grade 12 public school teachers in the US, approximately three-quarters of teachers reported that their classrooms contained only a few computers that all children share or take turns using. In addition, in previous research examining social interaction around the computer, researchers often provided only one or two computers to observe children's interactions around the computer (e.g., Muller and Perlmutter 1985; Underwood et al. 2000). Furthermore, usually more than two children were involved in the observations at any given time. As using the computer is a highly desirable activity in the elementary school classroom, the observed social interactions may simply be a function of children having to interact in order to gain access to the computer (Svensson 2000; Wang and Ching 2003).

Inkpen et al. (1995) examined differences in computer activity between pairs of Canadian elementary school children provided with only one computer (i.e., integrated-computer interaction) or with two computers, one for each child (i.e., parallel-computer interaction). Female pairs with one computer completed significantly more puzzles on the computer than female pairs playing side-by-side on two computers. The authors suggest that providing only one computer per pair of children encourages more interaction than when each child has their own computer. More research examining this issue is needed, however, as Inkpen et al. did not include mixed-gender pairings, or larger, more ecologically valid, group sizes in their study.

Parallel-computer interactions may actually benefit mixed-gender pairings, as boys and girls would not have to compete for control nor be assertive if each child had access to their own computer. To examine this issue, in the present study we examined differences in social interaction when children in small groups were provided with either one computer per group or one computer per child.

Number of Sessions

A crucial component of the impact of computer use on social interaction, however, also may be changes that occur in behavior over the course of time. It may be that the nature of the social interactions in computer-based activities will change as children become more familiar with the software. Changes in interactions may be especially noticeable as a function of the number of computers in the group. For example, Gillies (2003) indicated that when children work closely together in small groups, they may be aware of a peer's need for help or explanation and will provide assistance without being explicitly asked. During initial sessions with the computer, children may work together to understand the computer software in both the integrated and parallel conditions. However, once children in the parallel-computer condition become comfortable with the software they may rely less on their peers for assistance to complete the activity, and thus social interaction may decrease over time in this social context. Alternatively, because children in the parallel-computer condition have control of the computer at the same time as their group members, all group members may be able to enjoy the activity throughout all sessions, creating stability in their social interactions. Members of integrated-computer groups, where there is only one computer, must consistently work together if they wish to enjoy the activity, and therefore, interactions may remain stable over time. On the other hand, because a single person has control over the actions on the computer in the integrated-computer conditions, other group members may be forced to become onlookers (Parten 1932). Without direct involvement with the computer, some onlookers may become withdrawn from the group with the result that there is decreased social interaction over time or more off-task behavior. In the present study we explored children's social interactions during a computer-based activity across three sessions.

Summary of the Present Study

We explored two main research questions in the present study. First, do boys and girls' social interactions during a small group computer-based activity differ according to the school level (i.e., preschool versus elementary), computer-child ratio (integrated versus parallel), and gender composition (same-gender versus mixed-gender) of the groups, and do these effects change over time? Second, do boys and girls differ in the frequency with which they dominate the use of the computer in the integrated-computer groups where children have access to only one computer? To assess social interactions, we coded for the proportion of collaborative, off-task, and onlooker behaviors, as well as instances of dominating behavior. Our hypotheses were as follows:

> *Hypothesis 1*: It was expected that in elementary school, children in mixed-gender groups would show fewer collaborative behaviors than children in same-gender groups. Although in the present study each child in mixed-gender groups had a same-gender peer in their group, we still expected same-gender groups to engage in more collaborative behaviors than mixed-gender groups given the literature suggesting that in a computer context in particular, elementary school boys

in mixed-gender groups may continue to dominate girls. Expectations for the preschool population were less clear as there is a limited amount of research focusing on this issue with children in this school level. However, given the findings of Langlois et al. (1973), we hypothesized that preschoolers in mixed-gender groups would engage in more collaborative behaviors than same-gender groups.

Hypothesis 2: It was expected that collaborative behaviors in groups with access to only one computer per group would be higher than in groups with access to one computer per child given Inkpen et al.'s (1995) findings that providing only one computer per pair of children encouraged more interaction than when each child had their own computer. Whether children in mixed-gender groups might benefit from having access to one computer per child more so than children in same-gender groups, however, was speculative.

Hypothesis 3: It was expected that more off-task and onlooker behavior would occur in the integrated-computer condition than in the parallel-computer condition for children in both school levels.

Hypothesis 4: In the integrated-computer condition where children have access to only one computer, it was expected that elementary school boys would be more likely than elementary school girls to control the mouse and computer in the mixed-gender groups. Again, expectations for the preschool population were less clear so these analyses are exploratory.

Past research has not included a focus on changes over time in social interactions with computer-based activities, so our analyses of changes over time in these effects were exploratory. Given past research that indicates that children's prior level of computer experience may be an important influence in technology use (e.g., Rocheleau 1995; Subrahmanyam et al. 2001), in all analyses we controlled for children's prior level of computer experience. We also assessed children's level of engagement in the computer activity to gage their motivation level.

Method

Participants and Design

A total of 224 Canadian children participated in the study, including 116 preschoolers (*M* age=4 years *SD*=9 months with a range of 3 to 5 years) from 8 early childhood education centres and 108 fifth and sixth graders (*M* age=11 years, *SD*=7 months with a range of 10 to 12 years) from 3 elementary schools. Only children with active parental consent participated in the study. In total there were 57 girls and 51 boys in the 5^{th} and 6^{th} grade and 57 girls and 59 boys in the preschool population. The schools and centres were located in 3 mid-sized Canadian cities. We balanced the recruitment of the preschool and elementary schools across the 3 cities so that an equal number of preschool and elementary schools were included across each city. For example, preschoolers were recruited from one of 2 or 3 early childhood education centres in each of the 3 cities and elementary school participants were recruited from 1 elementary school in each of the same 3 cities. Children within each elementary school, or preschool centre, were assigned randomly to either a same-gender group or a mixed-gender group. All mixed-gender groups included two boys and two girls. Same-gender groups involved groups of 4 children except for 8 groups (4 groups in preschool and 4 groups in elementary school) which included 3 same-gender children. Each group was then assigned, randomly, to either an integrated-computer (one computer per group) or parallel-computer (one computer per child) condition. In total, there were 5 all-girl preschool groups, 5 all-girl elementary school groups, 5 all-boy preschool groups, 5 all-boy elementary school groups, 5 mixed-gender preschool groups and 5 mixed-gender elementary school groups in the integrated-computer condition; and 5 all-girl preschool groups, 5 all-girl elementary school groups, 5 all-boy preschool groups, 4 all-boy elementary school groups, 5 mixed-gender preschool groups and 4 mixed-gender elementary school groups in the parallel computer condition.

The design included four between and one within-subjects manipulation. The between-subjects variables were group composition (mixed versus same-gender), gender (boys versus girls), school level (elementary school versus preschool), and computer-child ratio (integrated-computers versus parallel-computers). The within-subjects variable involved time, with participants being exposed to the computer-based activity on three separate occasions.

Procedure and Materials

Each group of children was brought together to a familiar room within their school/preschool centre. One or four desktop PC computers with sound cards were present in the testing room. The *Thinkin' Things*® software (n.d.) used for each session included a series of activities such as music, problem solving, memory, and creativity tasks. To ensure age-appropriate materials, the preschoolers were presented with "Thinkin' Things 1" and the grade-schoolers were presented with "Thinkin' Things 3". These programs are highly attractive and interactive and therefore, very engaging for preschoolers and elementary school children.

In the parallel-computer condition, the four computers were placed in a "V" formation with two computers on each side of the “V”. A video camera was mounted at the head of the “V” such that all children’s faces could be seen. In the integrated-computer condition, the one computer was set up in the middle of the room, again with the camera situated to capture all participants. Children’s social behaviors and dominating behaviors were scored from the videotapes by research assistants.

Social Behaviors

A time sampling procedure was used for the social behaviors such that observations were scored at every 15-second interval. There were three categories of social behaviors that were scored. These included:

a) Collaborations—Behaviors were scored as collaborative, and given a score of 1, when participants *actively* pointed/gestured or demonstrated to peers to indicate how to do something on the computer.
b) Onlooker—Behaviors were scored as onlooker, and given a score of 1, when participants passively observed the computer activities.
c) Off-task—Behaviors were scored as off-task, and given a score of 1, when participants were engaged in an activity other than working on the computer or observing someone using the computer.

For each behavior for each child, total scores for each session were divided by the total number of observations in each session to obtain the proportion of behaviors in each session.

Dominating Behaviors—Dominating behavior was operationally defined as controlling the mouse and computer for an excessively disproportionate amount of time (50% of the time or more) in each session. Each child who controlled the equipment for 50% of the time or more for each session was given a score of 1 for that session, while the remaining children were given a score of 0. As all participants in the parallel-computer condition had access to a computer, this behavior was analyzed only for participants in the integrated-computer condition who could dominate the computer leaving others in their group with no turn.

Thirty percent of the videotapes were scored by two graduate research assistants to determine inter-rater reliability. Reliability was excellent for the scoring of the behaviors (Cohen’s kappa-0.94) and disagreements were resolved by discussion. The remaining videotapes were scored by one of the research assistants.

Children participated in the experimental session three times over a five-day period for ten minutes each time, with each session held on a separate day. Groups were introduced to the task immediately prior to the start of the first session. They were told that they would be permitted to play a game on the computer for a total of 10 minutes each day. To ensure that all children had the essential computer skills, children were given basic instructions with practice on how to use the mouse on the first day prior to the start of the first session. All participants were exposed to one software program that varied in difficulty as a function of school level (Thinkin’ Things 1 versus Thinkin’ Things 3, for preschool and sixth-graders, respectively). Four chairs were available for the children at each session but they were located at the side of the room in order to allow children to decide whether to use the chairs or not and how they wished to arrange chairs if they chose to use them. Children were videotaped and audio-taped. Two research assistants were in each session at all times. One operated the video-camera while the other addressed any computer problems. The children were told that the research assistants were not able to assist them with their computer activity but were only there to ensure that there were no computer problems. Research assistants, therefore, did not interact with the children during their computer session.

Computer Experience

A parent of each participant was asked to indicate on the consent form how frequently their child typically used the computer on a scale ranging from 1 “*daily*” to 6 “*never.*”

Post-Experimental Interview

At the end of the third session, a research assistant asked each child individually about their perceptions of the computer task. Specifically, each child was asked: “Did you enjoy the computer task?” Responses indicated that all children liked the computer activity.

Results

Results are first reported for the analyses conducted with the social behaviors (collaborative, off-task, and onlooker). Means and standard deviations of the social behaviors are outlined in Table 1. Second, results are reported for the analyses conducted with instances of dominating behaviors in the integrated-computer condition, with means and standard deviations shown in Table 2. Significant results from the primary analyses are shown in Table 3 and plots examining significant interactions are revealed in Figs. 1, 2, 3, and 4. For all analyses, we controlled for children’s prior level of computer experience. Parent reports indicated that the mean frequency of typical computer use for preschoolers was once a week ($M=2.15$, $SD=1.51$) and for elementary school children was between daily and once a week ($M=1.53$, $SD=1.21$). To examine whether there

Table 1 Mean proportion (raw scores) of collaborative, off-task, and onlooker behaviors as a function of school level, condition, gender, gender composition of groups, and time.

School level						
Condition	Girls			Boys		
Group composition Time	Collaborative *M (SD)*	Off-task *M (SD)*	Onlooker *M (SD)*	Collaborative *M (SD)*	Off-task *M (SD)*	Onlooker *M (SD)*
Early childhood						
Parallel computers (One per child)						
Mixed-gender groups						
Time 1	.13 (.12)	.06 (.08)	.21 (16)	.04 (.04)	.09 (.13)	.18 (.12)
Time 2	.10 (.10)	.10 (.11)	.21 (.15)	.10 (.08)	.06 (.06)	.20 (.13)
Time 3	.10 (.11)	.10 (.16)	.43 (.36)	.11 (.08)	.10 (.12)	.17 (.17)
Same-gender groups						
Time 1	.06 (.09)	.10 (.08)	.27 (.24)	.05 (.06)	.11 (.14)	.19 (.13)
Time 2	.07 (.07)	.05 (.06)	.19 (.10)	.06 (.07)	.16 (.34)	.17 (.15)
Time 3	.08 (.10)	.06 (.12)	.19 (.10)	.04 (.05)	.12 (.27)	.21 (.15)
Integrated computer (One per group)						
Mixed-gender groups						
Time 1	.11 (.11)	.12 (.15)	.42 (.29)	.13 (.16)	.16 (.14)	.57 (.26)
Time 2	.08 (.11)	.12 (.09)	.55 (.31)	.08 (.08)	.13 (.15)	.55 (.31)
Time 3	.10 (.10)	.07 (.07)	.67 (.36)	.10 (.11)	.07 (.07)	.56 (.38)
Same-gender groups						
Time 1	.02 (.03)	.24 (.24)	.50 (.34)	.11 (.15)	.21 (.20)	.48 (.22)
Time 2	.08 (.08)	.17 (.19)	.52 (.34)	.09 (.07)	.19 (.23)	.50 (.34)
Time 3	.09 (.13)	.18 (.19)	.49 (.35)	.05 (.07)	.25 (.26)	.48 (.34)
Elementary school						
Parallel computers (One per child)						
Mixed-gender groups						
Time 1	.00 (.00)	.01 (.01)	.05 (.06)	.00 (.00)	.01 (.01)	.06 (.04)
Time 2	.01 (.02)	.00 (.00)	.04 (.04)	.01 (.02)	.01 (.01)	.05 (.02)
Time 3	.00 (.00)	.01 (.01)	.04 (.03)	.03 (.04)	.01 (.02)	.04 (.04)
Same-gender groups						
Time 1	.05(.11)	.02 (.05)	.06 (.04)	.01 (.01)	.02 (.03)	.04 (.04)
Time 2	.02 (.03)	.01 (.01)	.04 (.04)	.03 (.06)	.01 (.01)	.06 (.06)
Time 3	.01 (.04)	.01 (.01)	.05 (.05)	.02 (.04)	.01 (.01)	.05 (.06)
Integrated computer (One per group)						
Mixed-gender groups						
Time 1	.10 (.11)	.02 (.05)	.69 (.24)	.10 (.08)	.02 (.03)	.58 (.24)
Time 2	.08 (.07)	.09 (.17)	.65 (.27)	.06 (.07)	.09 (.12)	.55 (.27)
Time 3	.05 (.04)	.16 (.20)	.57 (.28)	.09 (.10)	.12 (.12)	.48 (.27)
Same-gender groups						
Time 1	.07 (.07)	.03 (.06)	.67 (.31)	.16 (.10)	.01 (.02)	.58 (.30)
Time 2	.14 (.09)	.01 (.01)	.66 (.31)	.12 (.07)	.01 (.01)	.61 (.28)
Time 3	.12 (.09)	.01 (.01)	.68 (.31)	.12 (.10)	.02 (.06)	.58 (.30)

Means are raw proportion scores (ranging from 0 to 1). Analyses were conducted on the transformed scores. Higher scores indicate more collaborative, off-task, and onlooker behaviors.

were significant school level or gender differences in computer experience, a 2 (school level) by 2 (gender) ANOVA was conducted. The only significant effect was for school level, with higher levels of computer use reported for elementary school students than for preschoolers, $F(1,220)=7.27$, $p<.05$, partial $\eta^2=.04$.

Hierarchical linear modeling (HLM; Version 6.0; Raudenbush et al. 2005) was used to control for the nested nature of the data as results may not be correctly estimated if the shared variance among children who share the same group is not considered. HLM can be used to account for longitudinal data in which children's data

Table 2 Mean instances of computer dominating behavior in the integrated computer condition as a function of school level, gender, gender composition of groups, and time.

School level Group composition	Girls	Boys
Time	Mean (SD)	Mean (SD)
Early childhood		
Mixed-gender groups		
Time 1	.30 (.48)	.00 (.00)
Time 2	.20 (.42)	.10 (.32)
Time 3	.40 (.52)	.10 (.32)
Same-gender groups		
Time 1	.26 (.45)	.15 (.37)
Time 2	.26 (.45)	.20 (.41)
Time 3	.26 (.45)	.15 (.37)
Elementary school		
Mixed-gender groups		
Time 1	.00 (.00)	.40 (.52)
Time 2	.10 (.32)	.30 (.48)
Time 3	.00 (.00)	.40 (.52)
Same-gender groups		
Time 1	.20 (.41)	.18 (.39)
Time 2	.15 (.37)	.12 (.33)
Time 3	.20 (.41)	.18 (.39)

Means are raw scores (ranging from 0 to 1). Higher scores indicate higher instances of dominating behavior.

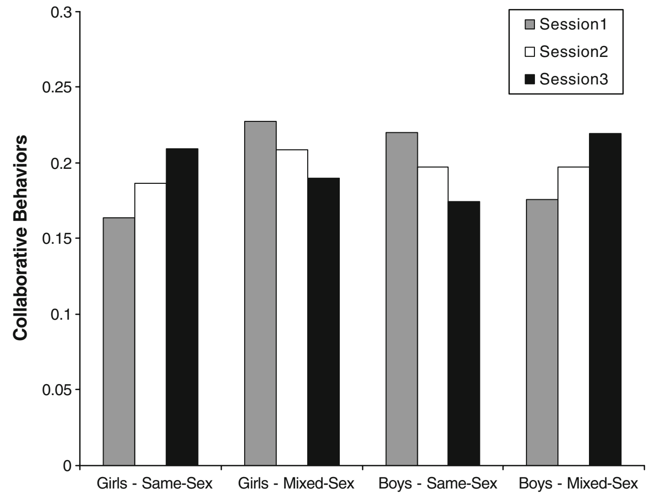


Fig. 1 Graph outlining the significant time by group composition by gender interaction for collaborative behaviors (model predicted scores).

includes observations over time (within-persons) and comparisons of observations between children (between-persons, e.g., Singer and Willett 2003), as well as comparisons between groups of children (between groups). Achenbach and Rescorla (2006. p. 161) provide the following example: "some studies might necessitate a 3-level model. For example, a study might compare aggressive syndrome scores over time in individuals (level 1) as a function of gender, SES, and referral status (level 2) in three different countries, such as the United

Table 3 Significant HLM results for behaviors.

	Parameter	Collaborative coefficient (SE)	Onlooker coefficient (SE)	Off-Task coefficient (SE)	Dominating coefficient (SE)
Between-persons					
Gender X school-level	γ_{04}				.47 (.19)*
Gender X group composition X school-level	γ_{06}				.52 (.23)*
Time X gender X group composition	γ_{12}	.10(.03)**			
Time X gender X condition	γ_{13}	.13(.03)**			
Between-groups					
Condition	γ_{002}	−.37 (.07)***	−.20 (.01)***	−.05 (.03)**	
School-level	γ_{003}		−.03 (.01)**	−.10 (.02)***	
Group composition X School-level	γ_{005}	−.20(.07)**			
School-level X condition	γ_{006}	−.34 (.07)***	−.08 (.01) ***		
Group composition X school-level X condition	γ_{007}			−.03 (.02)*	
Time X group composition	γ_{101}			.02 (.01)*	
Time X school-level	γ_{103}			.01 (.01)*	
Time X group composition X school-level	γ_{105}			.01 (.01)*	
Time X group composition X condition X school-level	γ_{107}			−.02 (.01)**	

Notes. *$p<.05$; **$p<.01$; ***$p<.001$. SE=Standard Error. Only significant results are included in the table. As all the factors were standardized before entering the model, coefficients can be interpreted as measures of effect size.

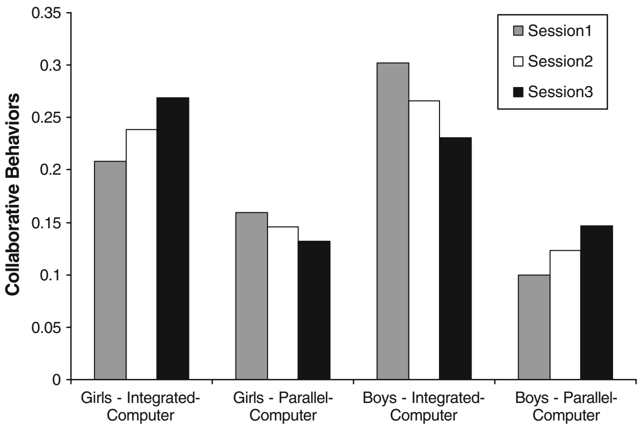


Fig. 2 Graph outlining the significant time by condition by gender interaction for collaborative behaviors (model predicted scores).

States, the Netherlands, and Korea (Level 3).” This three-level example is similar to the analyses conducted in the present study: level 1 (within persons), level 2 (between persons), and level 3 (between groups).

Specifically, the HLM analyses were conducted using a full factorial model (i.e., a $3\times2\times2\times2\times2$ design) with three levels (i.e., within persons, between persons, and between groups). The within-persons factor was time, with three

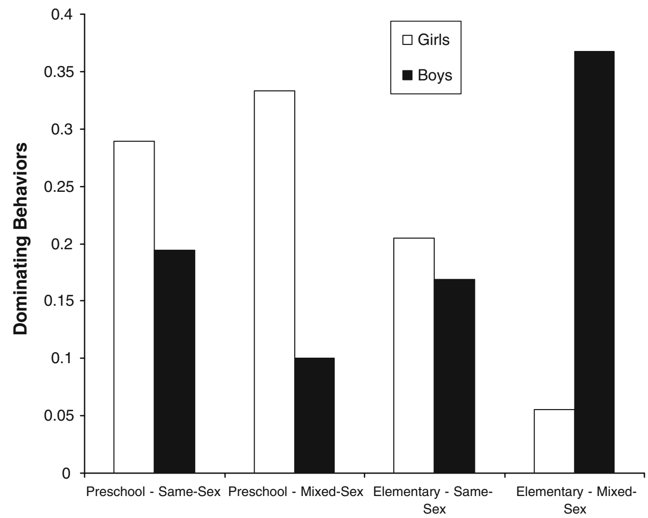
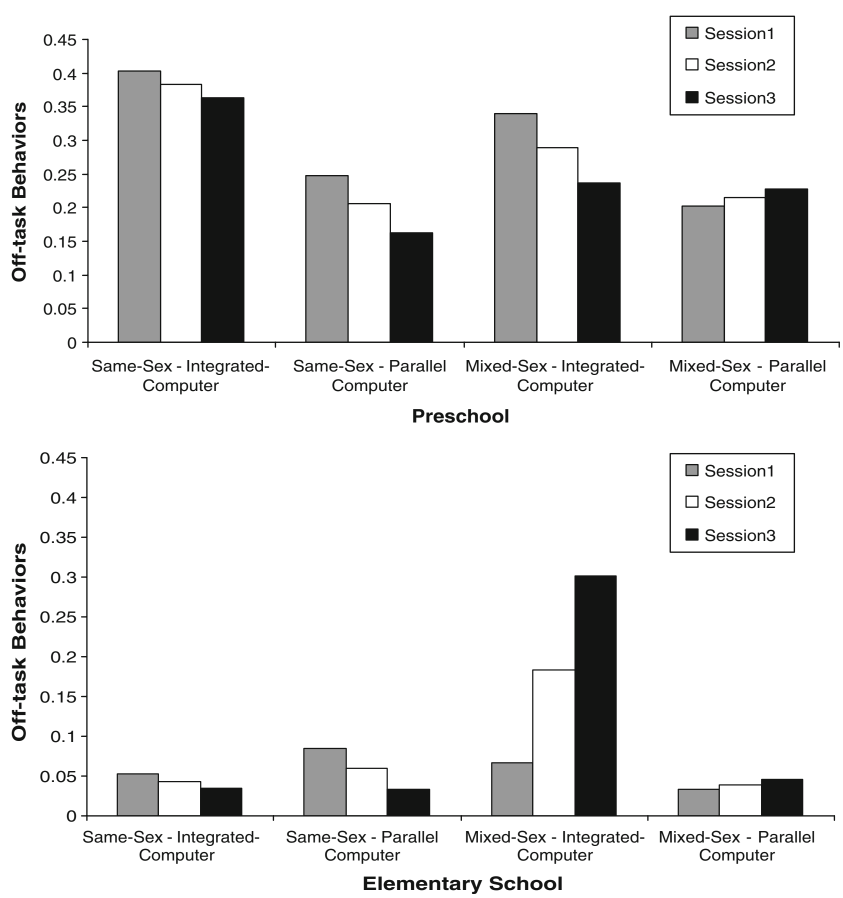


Fig. 4 Graph outlining the significant school level by group composition by gender interaction for dominating behaviors (model predicted scores).

separate sessions, and was entered as a level-1 variable. The between-persons or fixed factor at the child level was gender (boy, girl) and was entered as a level-2 factor. Level-2 factors are constant across time, and are therefore fixed

Fig. 3 Graph outlining the significant time by condition by gender by school level interaction for off-task behaviors (model predicted scores).



factors. The between-groups or fixed factors at the group level were group composition (mixed-gender, same-gender), and condition (integrated-computer, parallel-computer). These variables were entered as level-3 factors. Level-3 factors also are constant across time and are therefore fixed factors. We were not able to include school characteristics as a level-4 in the HLM analysis (to represent the fact that in our study children were nested within group within school) because HLM cannot fit a four-level model and because we had only a small number of schools represented in our study. Therefore, the factor related to school characteristics, school-level (preschool, elementary school), was included at the group level (i.e., level-3).

Interactions among factors also were entered in the analyses at the appropriate level (e.g., interactions with gender were entered in level-2). In HLM, interactions can be modeled across levels (Raudenbush et al. 2005). The equation for the level-1 within-persons model is presented in Equation One. The coefficients are interpreted similarly to a regular regression equation.

$$OutcomeVariable_{ij} = \pi_{oi} + \pi_{1i}(TIME) + e_{ij} \quad (1)$$

The equations for the between-persons model at level-2 are presented in Equations Two and Three. These equations specify that the level of the outcome variable and the rate of change across time in the outcome variable is a function of differences between girls and boys as well as interactions between gender of the child and other factors.

$$\begin{aligned}\pi_{oi} = {} & \gamma_{00} + \gamma_{01}(Gender) + \gamma_{02i}(GenderXGroupComposition) \quad (2)\\ & + \gamma_{03i}(GenderXCondition) + \gamma_{04i}(GenderXSchoolLevel)\\ & + \gamma_{05i}(GenderXGroupCompositionXCondition)\\ & + \gamma_{06i}(GenderXGroupCompositionXSchoolLevel)\\ & + \gamma_{07i}(GenderXConditionXSchoolLevel)\\ & + \gamma_{08i}(GenderXGroupCompositionXConditionXSchoolLevel)\\ & + r_{0j}\end{aligned}$$

$$\begin{aligned}\pi_{1i} = {} & \gamma_{10} + \gamma_{11}(Gender) + \gamma_{12i}(GenderXGroupComposition) \quad (3)\\ & + \gamma_{13i}(GenderXCondition) + \gamma_{14i}(GenderXSchoolLevel)\\ & + \gamma_{15i}(GenderXGroupCompositionXCondition)\\ & + \gamma_{16i}(GenderXGroupCompositionXSchoolLevel)\\ & + \gamma_{17i}(GenderXConditionXSchoolLevel)\\ & + \gamma_{18i}(GenderXGroupCompositionXConditionXSchoolLevel)\\ & + r_{1j}\end{aligned}$$

The equations for the between-groups model at level-3 are presented in Equations Four and Five. These equations specify that the level of the outcome variable and the rate of change across time in the outcome variable is a function of between-group differences in group composition, condition, school level, as well as interactions among these factors.

$$\begin{aligned}\beta_{ooi} = {} & \gamma_{000} + \gamma_{001}(GroupComposition) \quad (4)\\ & + \gamma_{002i}(Condition) + \gamma_{003i}(SchoolLevel)\\ & + \gamma_{004i}(GroupCompositionXCondition)\\ & + \gamma_{005i}(GroupCompositionXSchoolLevel)\\ & + \gamma_{006i}(ConditionXSchoolLevel)\\ & + \gamma_{007i}(GroupCompositionXConditionXSchoolLevel)\\ & + u_{00j}\end{aligned}$$

$$\begin{aligned}\beta_{10i} = {} & \gamma_{100} + \gamma_{101}(GroupComposition) \quad (5)\\ & + \gamma_{102i}(Condition) + \gamma_{103i}(SchoolLevel)\\ & + \gamma_{104i}(GroupCompositionXCondition)\\ & + \gamma_{105i}(GroupCompositionXSchoolLevel)\\ & + \gamma_{106i}(ConditionXSchoolLevel)\\ & + \gamma_{107i}(GroupCompositionXConditionXSchoolLevel)\\ & + u_{10j}\end{aligned}$$

The error components of these equations allow individuals and groups to differ randomly from each other. In addition, all analyses were conducted with children's prior level of computer experience as a control variable, entered in level-2 as a fixed variable. The collaborative, off-task, and onlooker behaviors showed positive skews and kurtosis, and therefore, a square root transformation was applied to the data prior to analysis (Cohen et al. 2003; Raudenbush et al. 2004).

For each behavior, an unconditional means model was first tested to examine whether there was sufficient variability in within-persons, between-persons, and between-groups sources of variation in the behaviors to warrant adding the fixed factors. Next an unconditional growth model was tested to assess whether, without the fixed factors, there were significant overall changes in the behaviors across time. Finally, the fixed factors and interaction terms were included in each model to assess their impact on each of the behaviors. To characterize the nature of significant 3 and 4-way interactions, graphs using model-predicted outcomes were constructed following instructions set by Singer and Willett (2003). Post-hoc analyses of significant interactions were conducted with the model-predicted outcomes in HLM.

Research Question 1: Do boys and girls' social interactions during a small group computer-based activity differ according to the school level (i.e., preschool versus elementary), computer-child ratio *(integrated versus parallel), and gender composition (same-gender versus mixed-gender) of the groups, and do these effects change across the three sessions?*

To address this research question, we conducted analyses for each of the observed social behaviors: collaborative, off-task, and onlooker.

Collaborative

We predicted in Hypothesis 1 that preschoolers in mixed-gender groups would engage in more collaborative behaviors than same-gender groups, but that elementary school children in mixed-gender groups would show fewer collaborative behaviors than children in same-gender groups. In other words, we predicted that there would be a significant interaction between group composition and school level for collaborative behaviors. Furthermore, in Hypothesis 2, we predicted that there would be a significant main effect for condition, in that collaborative behaviors in groups with access to only one computer per group would be higher than in groups with access to one computer per child. These hypotheses were tested with the HLM analyses as outlined above.

The unconditional means model demonstrated significant variability in within-persons, between-persons, and between-groups sources of variation in collaborative behaviors, all ps<.001. The unconditional growth model showed a non-significant effect for slope reflecting no significant overall changes in collaborative behaviors across time, $t(670)=.11$, $p>.05$. The significant results for collaborative behaviors when main effects and interactions were included in the model are outlined in Table 3. The main effect for condition was significant but was qualified by a significant interaction between condition and school level. Preschoolers' collaborative behaviors did not significantly differ between the integrated-computer (M proportion=.08) and parallel-computer conditions (M proportion = .07), $t(28)=-.47$, $p>.05$. In contrast, but consistent with our hypothesis, children in elementary school engaged in more collaborative behaviors in the integrated-computer condition (M proportion=.10) than in the parallel-computer condition (M proportion = .02), $t(26)=-9.09$, $p<.001$.

There also was a significant interaction between school level and group composition. Consistent with our hypotheses, there were more collaborative behaviors for preschoolers in the mixed-gender groups (M proportion=.10) than in the same-gender groups (M proportion = .07), $t(28)=2.20$, $p<.05$. Although descriptively there were fewer collaborative behaviors in the mixed-gender groups (M proportion=.05) than in the same-gender groups (M proportion = .07) for elementary school children, that difference was not significant, $t(26)=-1.10$, $p>.05$.

Two 3-way interactions were significant, time X gender X group composition and time X gender X condition. A plot of the time X gender X group composition interaction shown in Fig. 1 revealed that for both boys and girls, there was not a significant overall difference in collaborative behaviors between same-gender and mixed-gender groups, $t(37)=.63$, $p>.05$ for girls and $t(36)=-.20$, $p>.05$ for boys. In addition, there was a significant interaction between group composition and time for both girls and boys, $t(338)=-3.40$, $p<.01$ for girls and $t(326)=2.75$, $p<.01$ for boys. However, the direction of the interaction effect differed between boys and girls. Girls in same-gender groups increased in collaborative behaviors over time while girls in mixed-gender groups decreased in collaborative behaviors over time. In contrast, boys in mixed-gender groups increased in collaborative behaviors over time while boys in same-gender groups decreased in collaborative behaviors over time.

A plot of the time X gender X condition interaction (see Fig. 2) indicated that there was a significant main effect for both girls and boys in the integrated-computer condition to engage in more collaborative behaviors than girls and boys in the parallel-computer condition, $t(37)=-2.67$, $p<.05$ and $t(36)=-4.18$, $p<.001$, respectively, but that difference increased over time for girls, $t(338)=3.52$, $p<.01$ and decreased over time for boys, $t(326)=4.98$, $p<.001$.

Off-task

In Hypothesis 3, we predicted that a significant main effect for condition, in more off-task behavior would occur in the integrated-computer condition than in the parallel-computer condition for children in both school levels. This was tested using the same HLM analyses outlined above but with off-task behaviors as the dependent variable. The unconditional means model demonstrated significant variability in within-persons, between-persons, and between-groups sources of variation in off-task behaviors, all ps<.001. The unconditional growth model showed a non-significant effect for slope reflecting no significant overall changes in off-task behaviors across time, $t(670)=-.86$, $p>.05$. The significant results for off-task behaviors when main effects and interactions were included in the model are outlined in Table 3. There was a significant main effect for condition and school level. These main effects, however, were qualified by significant 2- and 3-way interactions (school level X time, time X group composition, school level X group composition X condition, time X school level X group composition) as well as a significant 4-way interaction among time X school X group composition X condition. Only the 4-way interaction is interpreted further. A plot outlining the interaction is shown in Fig. 3.

In preschool, consistent with our hypotheses, children in the same-gender groups were significantly more likely to be off-task in the integrated-computer condition than in the parallel-computer condition across all 3 sessions, $t(18)=-2.86$, $p<.05$, while the difference in off-task behaviors between the two conditions significantly decreased over time for the mixed-gender groups, $t(116)=3.12$, $p<.01$. In contrast, elementary school children in same-gender groups engaged in limited off-task behavior in both the integrated-computer and parallel-computer conditions, $t(17)=1.04$, $p>.05$, but children in the mixed-gender groups significantly increased in off-task behavior over time in the integrated-computer condition, $t(104)=-6.87$, $p<.001$.

Note that elementary school children in the parallel-computer condition sometimes did not exhibit these behaviors (e.g., 3 out of 48 cells for collaborative behaviors and 1 out of 48 cells for off-task behaviors). Rerunning the collaborative and off-task analyses without the elementary school children in the parallel-computer conditions (first conducting the analyses with just the preschoolers, and then with the integrated-computer conditions only) did not change the results reported above for these behaviors.

Onlooker

In Hypothesis 3, we also predicted a significant main effect for condition, in that more onlooker behavior would occur in the integrated-computer condition than in the parallel-computer condition for children in both school levels. This was tested using the same HLM analyses outlined above but with onlooker behaviors as the dependent variable. The unconditional means model demonstrated significant variability in within-persons, between-persons, and between-groups sources of variation in onlooker behaviors, all ps$<.001$. The unconditional growth model showed a non-significant effect for slope reflecting no significant changes in overall onlooker behaviors across time, $t(670)=-.76$, $p>.05$. The significant results for onlooker behaviors when main effects and interactions were included in the model are outlined in Table 3. There was a significant main effect for condition which was qualified by a significant interaction between condition and school level. Consistent with our hypotheses, both preschool and elementary school children engaged in more onlooker behaviors in the integrated-computer condition (M proportion=.52 for preshoolers and .61 for elementary children) than in the parallel-computer condition (M proportion=.22 for preshoolers and .05 for elementary children), $t(28)=-19.33$, $p<.001$ and $t(26)=-50.84$, $p<.001$, respectively, but that difference was more pronounced with elementary school children.

Research Question 2: Do boys and girls differ in the frequency with which they dominate the use of the computer in the integrated-computer groups where children have access to only one computer?

With Hypothesis 4, recall that our analyses for the preschoolers were exploratory, but that we hypothesized a main effect for gender for dominating behaviors with elementary school children, in that elementary school boys would be more likely than elementary school girls to control the mouse and computer in mixed-gender groups. As all participants in the parallel-computer condition had access to a computer, this behavior was analyzed only for participants in the integrated-computer condition who could dominate the computer leaving others in their group with no turn. Each child who controlled the equipment for 50% of the time or more for each session was given a score of 1 for that session in order to indicate dominating behavior, while the remaining children were given a score of 0. Given the dichotomous nature of this outcome variable, the assumption of normality was not realistic and the Bernoulli distribution was selected for this variable in HLM (as recommended by Raudenbush et al. 2004, 2005). The Bernoulli model is a special case of the binomial distribution when the outcome variable is dichotomous and involves predicting the probability that children will or will not dominate the computer. The significant results for dominating behaviors when main effects and interactions were included in the model are outlined in Table 3. There was a significant interaction between school level and gender, which was qualified by a significant 3-way interaction among school level, gender, and group composition. A plot outlining the three-way interaction is shown in Fig. 4. There was a higher probability that girls rather than boys would dominate the computer equipment in mixed-gender groups in preschool, $t(18)=-6.13$, $p<.001$. In contrast, and consistent with our hypothesis, in elementary school there was a higher probability that boys rather than girls would dominate the computer equipment in mixed-gender groups, $t(18)=6.90$, $p<.001$. In addition, domination of the computer was more probable with preschool girls than with preschool boys in same-gender groups, $t(37)=-4.27$, $p<.001$, but there was no significant difference between boys and girls in elementary school same-gender groups, $t(35)=-.77$, $p>.05$.

Discussion

The first question in the present study addressed whether boys and girls' social interactions during a small group computer-based activity would differ according to the school level (i.e., preschool versus elementary), computer-child ratio (integrated versus parallel), and gender composition (same-gender versus mixed-gender) of the groups, and whether these effects would change over time. Consistent with our hypothesis, preschoolers engaged in more collaborative behaviors in mixed-gender groups than in the same-gender groups. Results from our examination of off-task behaviors with children in this school level offer an explanation for this finding. Mixed-gender groups in preschool engaged in fewer off-task behavior than their same-gender peers, particularly in the integrated computer condition. It is likely that a mixed-gender grouping with children in this school level encouraged less distraction and off-task behavior, and therefore, resulted in more collaborative behaviors.

In contrast to findings from studies by Underwood and colleagues (Underwood et al. 1993, 1994, 2000; see also Fitzpatrick and Hardman 1994; Light et al. 2000) and our own hypothesis, however, collaborative behaviors did not significantly differ across mixed-gender and same-gender groups with the elementary school children. It may be that having a same-gender peer in each of the mixed-gender groups offset the typical disadvantage found with elementary school girls in mixed-gender groups. Alternatively, perhaps with computers being ubiquitous in both homes and schools today, elementary school boys no longer have an advantage over girls with computers.

However, the conclusion that elementary school children's social interaction may not be affected by gender composition in small groups may be premature. For example, for elementary school children in the integrated-computer condition, same-gender groups engaged in limited off-task behaviors over time while mixed-gender groups significantly increased in off-task behavior. These results suggest that in contrast to the results we found with preschoolers, elementary school same-gender groups are less likely than mixed-gender groups in the integrated-computer condition to get distracted and off-task.

In addition, analyses of changes in social interaction across the three sessions indicated that girls in same-gender groups increased in collaborative behaviors while girls in mixed-gender groups decreased in collaborative behaviors over time. In contrast, boys decreased in sharing activities over time if they were in the same-gender condition but boys in mixed-gender groups increased in collaborative behaviors over time. These differential results over time in collaborative behaviors between boys and girls as a function of the gender composition of the group offer some support for the large amount of research that suggests that more positive social interaction occurs for girls in same-gender pairings over mixed-gender pairings (e.g., Fitzpatrick and Hardman 1994; Light et al. 2000; Underwood et al. 1994, 2000).

For same-gender groups in particular, it appears that as girls became more comfortable with the computer software, they started to collaborate with each other. Although the boys were still very engaged with the task, their level of collaborative behavior tended to decrease as they became more familiar with the software. Their engagement, then, may be similar to what has been suggested by Lee (1993) in previous research conducted with elementary school children in South Korea. Boys tend to be more goal-oriented on the computer and they interact with one another to find out how to use the programs, and generally how to do better. These behaviors would be expected to decrease over time as boys become more familiar with the software. Within same gender groups, then, boys may gain most from group activities when encountering novel tasks and software, whereas girls may benefit most when they are more familiar with software. On the other hand, educators who are aware of these potential gender differences in collaborative behaviors when introducing new software may be able to prevent these differences by explicitly encouraging both boys and girls to collaborate with each other at the start of using new software as well as over time. Overall, these results confirm that the nature of social interactions in computer-based activities may change over time as children become more familiar with the software, and highlight the importance of including a focus on change over time in studies examining computer-based social interactions.

Also consistent with our hypotheses, more social interaction occurred when there was only one computer available for the children to use than when each child could use their own computer. While individualized learning clearly is important, enhancing social interaction in the classroom also can enhance learning opportunities (Abrami 2001; Azmitia and Perlmutter 1989; Lou et al. 2001) and in this latter case, having a limited number of computers in the classroom may translate to an advantage rather than to a barrier for learning. Our results suggest that the best way to encourage social interaction in a learning context with a computer-related activity might be to limit the number of computers in the classroom. Importantly, while children in the integrated-computer condition were more likely than children in the parallel-computer condition to be onlookers, they remained engaged positively in the task. In fact, in an interview at the end of the study, each child indicated that they enjoyed the computer activity. Clearly, working on the computer still is a highly prized activity for both preschoolers and elementary school children.

School level, however, was an important factor for how boys and girls engaged socially depending on the computer-child ratio in their group. With preschoolers, the number of computers that were available did not affect the amount of collaborative behaviors. Preschoolers engaged in similar amounts of collaborative behaviors regardless of whether they were in the integrated-computer or parallel-computer condition. In contrast, at the elementary school level, the number of computers available dictated the amount of collaborative behaviors that took place, with less social interaction occurring when there were more computers available. It appears that preschoolers were more likely to work collaboratively in the parallel-computer condition than elementary school children. The onlooker results verify that conclusion. Preschool children engaged in more onlooker behaviors in the parallel-computer condition than elementary school children, suggesting that they were working together even when they each had access to a computer. In addition, this significant interaction between school level and number of computers per group did not depend on the gender composition of the group, suggesting that having access to one computer per child does not differentially affect collaborative behaviors in same-gender versus mixed-gender groups. Clearly, if the goal of educators is to enhance computer-based learning through collaborative opportunities, limiting the number of computers that are available in the classroom is important for elementary school children more so than for preschoolers.

Our second research question addressed whether boys and girls differ in the frequency with which they dominate the use of the computer in the integrated-computer groups where children have access to only one computer. Elementary school boys on average were more likely than girls to dominate the mouse and computer in mixed-gender groups, supporting previous research findings in this area (Hooper 2003; Reis 1998; Underwood et al. 2000). In contrast, in preschool, girls were more likely to be dominant than boys in mixed-gender groups, lending support to the finding reported by Langlois et al. (1973) that 3-year-old boys engaged in more positive behavior when partnered with a girl than when partnered with a same-gender peer. As some researchers such as Ausch (1994) and Fitzpatrick and Hardman (2000a) have suggested that elementary school girls may be more likely to demonstrate assertive or controlling behaviors when partnered with boys during non-computer-based tasks than during computer-based tasks, it may be that in preschool there is no clear differentiation between computer-based and non-computer-based tasks with mixed gender groups, with the result that preschool girls displayed more dominating behaviors than boys in our study. This hypothesis is speculative, however; further research is needed in order to interpret this finding.

Clearly, even though gender differences in use of the computer have dissipated (see Gross 2004), the gender composition of small groups doing computer-based activities is still an important factor for educators to consider. For example, in computer-based activities with elementary school children, providing the group with access to more than one computer might be the best option if the goal is for all children to have a turn with the computer. If the computer merely serves as the vehicle of instruction, but the group interaction is the goal, one computer could be used but most likely one of the boys would be operating it. In contrast, in preschool our results suggest that it would most likely be one of the girls who would be dominating the computer.

There are several limitations to this study. One important shortcoming stems from our reliance on only one software program. It is conceivable that children's involvement varies with the appeal of the program. Each child at the end of the study, however, indicated that they enjoyed the activity. In addition, boys and girls of each school level were randomly assigned to same-gender and mixed-gender groups, as well as integrated versus parallel computer conditions, thus controlling for different levels of interest in the software across these groups. Nevertheless, future research should include a range of software. Children in the study also encompassed two school levels which were enrolled in different school systems (i.e., preschool versus elementary school). Although we balanced recruitment of the preschoolers and elementary school children across the three cities involved in our study, there still may be differences between children as a function of the school level beyond their difference in age. In addition, generalizability of our findings may be of greater relevance for preschoolers than for elementary school children, given that elementary school children likely were aware that the computer activity used in the present study did not “count” in the same way as other school work. Furthermore, including children in the 6th grade may have affected the generalizability of the results because some of the older children may have started puberty, which may have affected their group interactions. The 6th grade children in the present study were all in an elementary school rather than in middle school, so the results for children in this school level may also differ in regions where 6th grade children are in middle school. Another limitation is that due to the exploratory nature of some of our research questions, we did not control for conducting multiple statistical tests, and thus caution should be applied to the interpretation of our findings. Finally, children were allowed to work on the computer only for a short amount of time during each session. At the same time, however, including three sessions in the present study was a major strength of the study design.

In summary, this study was the first to examine gender differences and changes over time in social interaction with computer-based activities, specifically as a function of school level, gender and group composition. Given the recent increases in access to computers in schools and in the home, having a more current picture of how boys and girls interact in computer contexts is critical. Moreover, the past widespread concern about gender-related differences in computer use and attitudes (see Subrahmanyam et al. 2001 for a review) supports the inclusion of more research in this area. In particular, it is important to investigate social interactions across different kinds of software for longer periods of time and to examine whether the results of the present study extend beyond social interaction behaviors and apply to specific learning indicators. Nevertheless, the results of this study make clear that as computers increasingly become an integrated part of the classroom, the gender composition in small groups needs to be a critical consideration, especially when collaborative computer-based learning contexts are being designed. For example, placing preschoolers in mixed-gender groups with one computer per child, but elementary school children in same-gender groups with only one computer per group, may be the most effective in facilitating social interaction for computer-based activities.

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