



A study of 5- to 6-year-old children's peer dynamics and dialectical learning in a computer-based technology-rich classroom environment [☆]

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Abstract

The aim of the study was to explore characteristics of 5- to 6-year-old kindergartners' peer dynamics during a seven week learning experience in a computer-based technology-rich classroom in the US. The children (9 boys and 9 girls) were placed in pairs by the classroom teacher, based on her perception of the their friendships. Measures of each child's computer proficiency were obtained at the beginning and conclusion of the experience, using a 20-item instrument called the individualized computer proficiency checklist (ICPC), developed for this study. Overall, the children showed an average gain of 38.5% on their ICPC scores. Paired children who differed in computer proficiencies but shared similar interests worked very well, exemplifying Vygotsky's dialectical constructivist perspective on peer teaching and learning characteristics. Their conversations displayed self-confidence, multiple perspective-taking skills, and reflective self-assessment. The pairs demonstrating limited computer proficiency frequently engaged in serial turn taking and nonpurposeful clicking on the computer screen. The study concludes with pedagogical implications for teachers.

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1. Introduction

Computer-supported collaborative learning has been known as an effective educational approach (Crook, 1994, 1998; Roschelle & Clancey, 1992). Several studies have reported a relationship between collaborative-learning behaviors and each learner's computer proficiency (Duhaney, 2000; Tiene & Luft, 2001a, 2002a, 2002b). The previous researchers, however, examined neither the phenomenological aspects of sharing hardware and software nor the collaborative learning behavior of young children in relation to their basic computer proficiency. Thus, the current study focused on kindergartners' collaborative engagement and learning behaviors emerging in a technology-rich classroom during a seven-week experience. The primary research question follows: What characteristics of 5- to 6-year-old kindergartners' collaborative learning behaviors emerged in the peer dynamics in an exploratory computer-based technology-rich classroom?

2. Literature review

2.1. *Deep learning experiences*

As early as kindergarten, small-group experiences supported with computer technology can promote deep learning; for example, children construct new meaningful learning experiences by creatively solving problems through examining the ideas and perspectives of others. Deep learning is promoted by active learner participation associated with constructivist social interaction such as collaborative learning (Biggs, 1987, 1993). Computer-based technology in the context of group learning promotes deep learning and critical thinking. When deep learning occurs, learners seek critical understanding of the material they are working on. This critical thinking supports constructive peer dynamics, learner self-assessment, and integration of new learning into existing knowledge (Newman, Johnson, Webb, & Cochrane, 1997).

2.2. *Vygotsky's dialectical constructivism and peer collaborative engagement*

Moshman (1982) has identified three types of constructivism: (a) endogenous constructivism, which emphasizes learner exploration; (b) exogenous constructivism, which recognizes the role of direct instruction with an emphasis on learners actively constructing their own knowledge representations; and (c) dialectical constructivism, which emphasizes the role of interaction among learners, their peers, and teachers, during which learners require scaffolding provided by teachers or experts as well as collaboration with peers. According to Vygotsky (1978), learning occurs within a social context, and interaction among learners and their peers is a necessary part of the learning process. Vygotsky's theory, one of the traditional interpretations of constructivism known as dialectical constructivism (Moshman), accommodates learners as collaborators in his perspective (Dalgarno, 2001). Based on Vygotsky's socio-cultural perspective of learners as collaborators, Crook (1998) suggested that computer technology allows a community of learners to enter a zone of proximal development as they create knowledge among co-working peers.

2.3. *Young children's peer collaboration in technology use*

Computer technology can be used in the early childhood classroom as a catalyst for collaborative small-group learning. A considerable body of literature supports this approach. Crook, for example, stated: “New technology offers a special potential for supporting the development of collaborative learning in early education” (Crook, 1998). He argued that technology-based activities can be especially effective when they help groups of young children explore ideas at developmentally meaningful levels and when they provide experiences within what Vygotsky termed “zones of proximal development (ZPD)” (Crook, 1991). Dalgarno (2001) provided a useful taxonomy of how different types of technology-based learning activities can facilitate dialectical constructivist inquiry, wherein ongoing interaction among learners helps them interpret new material and negotiate its meaning.

According to Crook (1998), three features of social interaction are essential to successful collaborative engagement. First, collaborating involves more than a set of experiences or understandings shared among participants; it entails knowing this state of mutuality exists. Mobilizing shared experiences into a genuine collaboration depends upon such projective capabilities that are highly intellectual. It depends upon knowing recursively that other knows what you know. Crook (1998) has proposed that using such mutuality may have an affective dimension as well as a cognitive significance for problem solving. Second, in computer-supported collaboration the possibility of creating productive common knowledge is likely improved by a rich supply of external resources. The collaborators will benefit from vivid and assessable referential anchors (Crook, 1994, 1998; Roschelle & Clancey, 1992). Finally, productive collaborations likely depend upon the quality of interpersonal relations already in place at the time some novel collaborative encounter is initiated. In short, participants will usually bring to these new encounters exchanged histories of joint activity conducted on other occasions and at other times. Indeed, empirical evidence suggests that friendship is a significant factor in collaborative problem solving. In collaborative engagement and peer dynamics, the character of interpersonal relationships already existing in the group exerts a strong influence particularly when gender and ability differ (Crook, 1994, 1998).

2.4. *Can young children learn collaboratively?*

Crook (1998) argued that children begin cognitive learning in a co-operative and imitative relationship with another who is more experienced. Together they actively contribute to the propagation of collective knowledge. Young children's interest in establishing mutual knowledge seems very strong in Crook's view; in fact, every learning experience in which children engage is collaborative (Bruner, 1983; Crook, 1998).

Socially and cognitively, children are collaborative learners, but Crook questioned whether young children could learn collaboratively with new computer technology in a regular classroom environment not previously supportive of their success and effectiveness as collaborators:

... [Young children's] potential as collaborators arises from observations of what goes on in classrooms. But if we glance into a school playground, we soon notice children actively managing and engaging in collaborative routines. So, the challenge for developmental psychology is how to understand a certain discontinuity of function. On the 'playground' children might manage reciprocity very effectively; faced with the

agenda of their classroom, they may be much less successful and, thus, not very effective collaborators. We can now consider whether new technology can help us tackle this discontinuity. (243)

From Crook's perspective, young children collaborate and learn collaboratively. Providing naturalistic and learner-centered environments like "playgrounds," where children have the freedom to explore, negotiate, teach and share among themselves, and take charge of their own learning, seems to be critical in uncovering characteristics of young children's collaborative-learner behaviors in a technology-rich classroom.

2.5. Computer technology-rich classroom learning experiences and proficiencies

Computer use with young children requires careful investigation. Very little research-based evidence is available showing what learning gains might be expected from an infusion of computer technology, in part because very few classroom settings provide ready access to various forms of computer-based technology throughout the school day (Tiene & Luft, 2001b).

Enthusiastic about technology, young children may be less inhibited about working with computers than many adults (Clements, 1994; Haugland, 1999, 2000; Shade, 1999); but how do they respond to placement in a classroom with a great deal of technology? Some studies have examined the impact of technology-rich immersion on teaching and learning (Duhaney, 2000; Tiene & Luft, 2001a, 2002a, 2002b); however, the impact of such an environment upon the computer proficiency of young children has received little attention in the literature. Coughlin (1999) discussed a set of proficiencies that learners might be expected to develop in working with new technologies without empirically documenting skill levels or growth in proficiency. Duhaney documented specific changes in classroom activities that may result from introducing a significant amount of technology into the classroom, stressing the importance of technological proficiency in participants as a key to successful experiences in such settings.

Tiene and Luft (2001a&b; 2000a&b) have completed several quantitative studies capturing teachers' general perceptions of children's collaborative learning in the same technology-rich facility used in this study. The teachers in this setting reported that both they and their students improved their technological proficiency during the time they were immersed in this environment. The previous researchers, however, examined neither the phenomenological aspects of sharing hardware and software nor the collaborative learning behavior of the children in relation to their basic computer proficiency. Thus, Tiene and Luft's research, which dealt directly with the effectiveness of collaborative learning in a technology-rich classroom, did not capture the qualitative relationship between children's basic computer proficiency and collaborative-learning dynamics within the technology-rich classroom. Both the current study and research by Tiene and Luft were conducted in the Research Center for Educational Technology Ameritech Classroom.

3. Research methodology

3.1. Research design and procedure

The study was designed to explore collaborative behaviors of 5- to 6-year-old kindergartners in light of their computer proficiency. A mixed method of data collection was used. Baseline data

regarding individual children's basic computer proficiency were collected with the Individualized Computer Proficiency Checklist (ICPC) before and after immersion into the technology-rich environment (See Appendix A). The majority of qualitative data (children's conversation) was collected during the seven-week period when the children were in the technology-rich classroom daily for 2 h. The main procedures of the study include the following:

- September 2001–January 2002: weekly visit to the regular kindergarten classroom to become familiar with the children and build the ICPC instrument. Pairing occurred immediately before the children's first visit to the technology-rich classroom.
- February 4, 2002–March 22, 2002: daily visit to the computer-based technological learning environment to observe and document the children's interactions and behaviors using field notes and video camera. ICPC was completed during the first and last week of experience in the technology-rich classroom. Thus, the interval between the initial and final measurements was about six weeks.
- April 2002–September 2003: Data analysis

3.2. *Participants and pairing*

Eighteen 5- to 6-year-olds (9 boys and 9 girls) from culturally and linguistically diverse backgrounds participated in the study. They attended kindergarten at a child development center at a northeast Ohio university in the US. Most of the children's parents were college students or members of the faculty and staff of the university. Among the children, a set of twin boys (Andy and Phill), were nearly a year younger than the 3 oldest 6-year-olds (Palsan, Victor, and Mandy). One child (Ann) was identified as a learner with special needs in vision and learning delay. The average age of the children was 5 years and 7 months at the beginning of their experience in the technology-rich classroom. All but one child's family indicated that they had a home computer; however, in most cases, parents reportedly knew little about software developmentally appropriate for their young children and allowed them no more than 30 min of access to the computer per day at home because the computer was primarily used for adults' work or study. One parent indicated that son Mickey used the computer at home frequently because of his older sister's influence; these siblings often played with children's software together at home.

During the seven weeks in the technology-rich classroom, the children shared a computer in assigned pairs. Prior to experience in the technology-rich classroom, the lead teacher had arranged the pairing based solely on her observation of friendship patterns the children had established during the first semester of the school year; children's cognitive levels were not criteria for pairing. Her primary purpose was to pair them in a way that no child would feel conflicted in sharing the computer with his or her partner.

3.3. *Classroom settings*

The children's kindergarten classroom was designed to meet the criteria for developmental appropriateness set forth by the National Association for the Education of Young Children (1996). The kindergartners had one lead teacher, one assistant teacher, and one art teacher. They had access to a wide variety of media to explore and use in their mapping project, which was the curriculum theme of the academic year.

The technology-rich classroom, known as the Ameritech Classroom, was designed as a place for students and their teachers to work on class-defined projects using the latest technology. This setting included 12 networked computers with Internet access, a scanner, color printers, video-conferencing cameras connected to several computers, digital still-frame cameras, camcorders, word-processing tools (such as AlphaSmart), a variety of reference books for young children, art supplies, and two adjustable large tables and chairs for group work. Because the classroom had been designed for learners from kindergarten through high school, tables and chairs were all height-adjustable to create an age-appropriate physical environment. At the front of the room was a central instruction area with a computer, large projection screen, a VCR, and an Elmo video document camera. Software available for the children included the following: Microsoft Word, Golden Books Encyclopedia for Kids, Community Construction Kit, KidPix, Neighborhood MapMachine, Microsoft PowerPoint, Intel Video Still Camera Movie Maker, Diorama Designer, and Paint Shop.

3.4. Role of the researcher

The researcher was a participant-observer. In order to engage in learning experiences with the children and to capture the essence of their peer dynamics, the researcher remained with the children during the seven weeks of the technology-rich classroom experience, interacting (e.g., dialoguing, interviewing, exploring, assisting, learning) with them as a member of the learning community. During that time the researcher was more than participant-observer, becoming a “familiar friend” (e.g., Fine & Sandstrom, 1988, pp. 17–18), learning with the children and from their continuous discoveries of what they could do with the multiple forms of technology available to them. In fact, the children were eager to teach the researcher what they could do as peer teachers: “Eunny, come over here. Do you want to learn how to make the word larger than this? Go to this ‘number thing’ and click on the bigger number (clicked number 48). See! Wow, it’s really big!” (Field note, March 2002).

3.5. Data context and collection

3.5.1. Instrument and quantitative data

Using the ICPC before and after immersion in the technology-rich classroom, the researcher rated the children’s basic computer proficiency with data collected. Twenty tasks, observed and recorded as basic computer proficiency skills through ICPC, were assessed at four skill levels: fluent (four points: purposely or automatically shows the skill without hesitation or difficulty and exhibits it consistently); emerging (three points: tries a couple of times before the child exhibits the skill); needs assistance (two points: asks for help or asks “how to”); or not observed (one point: not shown or does not engage in using/showing particular skill). One graduate assistant and the researcher conducted a pilot study to assure the reliability and validity of the instrument. The interrater reliability of judgment and rating was 98%. The researcher used 2 or 3 periods of 5- to 7-min intervals to observe each skill before recording final scores in both initial and final measures.

3.5.2. *Before the technology-rich classroom experience*

At first, the children had two computers in the regular classroom. Two weeks before they began their work in the technology-rich classroom, they had five computers. During this time, however, the teacher did not use the technology as instructional tool; instead, the computers were available in one of their play-oriented learning centers. Each day, 2 to 4 children were assigned to different centers for 15–20 min. The computer center was one of the choices. Once children were assigned to the computer center, they simply explored Internet websites familiar to young children or played several available reading CDs.

3.5.3. *Technology-rich classroom observation and qualitative data collection*

Data collected to capture the children's peer dynamics included the researcher's field notes, naturalistic interview notes, children's conversations, and video records of their interactions. The researcher followed daily activities with the children to document their conversations, questions, and interaction characteristics. Daily activities were usually composed of

- 15–20 min of playing with software in pairs,
- 15 min of large-group discussion in preparation for small-group activities in the technology classroom,
- 30–40 min of small-group activities using software and hardware in pairs,
- 20–30 min of learning and exploring new tools introduced by technology support staff in large group as well as in pairs,
- 10–15 min of large-group reading of a children's book chosen by the children for the day, and
- 20 min of composing the daily reflection about their experience in the technology classroom.

Most of the software and hardware introduced in the technology-rich classroom were new tools for the kindergarteners. During the technology-rich classroom experience the children were exposed first in a large group to a variety of software for their map-making activities. Once they had learned how to play with new software, each pair went to the computer to play with the program. In some cases, the children could choose different activities independent of their partner. Thus, the data collected also revealed various peer dynamics outside the pairs.

3.6. *Data analysis*

Initial and final measures taken with the ICPC were counted quantitatively and analyzed descriptively using means and percentage. To investigate any statistically significant change between initial and final measures of each child's ICPC, the statistical test ANCOVA was used between initial and final score subject effects, using the final score as dependent variable (see Table 1).

Most data were collected and analyzed qualitatively. Children's conversation within the pairs, large-group discussion, dialogue with teachers, and informal interviews with the researcher were transcribed. Primary data analysis techniques included open, inductive, axial, and selective coding (Strauss & Corbin, 1990) as well as data reduction (Miles & Huberman, 1994; Shank, 2002). The purpose of data analysis was to find emerging patterns of peer dynamics among the children in light of the research question.

Multiple readings of the transcriptions were completed in the initial stage of open coding, which involved breaking down, examining, comparing, conceptualizing, and categorizing the data to capture any emerging pattern characterizing the children's learner behaviors in general. To further

Table 1
Subjects' growth in basic computer proficiency

	Pairings	Initial score	Final score	Improvement	Percentage improved
Girls					
	1. Ann	27	53	26	96
	Sangi	35	50	15	43
	2. Hyeemun	43	53	10	23
	Suna	45	57	12	27
	3. Joanna	47	56	9	19
	Marsha	44	57	13	30
	4. Sasha	45	61	16	36
	Mandy	37	67	30	81
	5. Annie	48	59	11	23
Boys					
	Al	41	55	14	34
	6. Augustine	41	58	17	41
	Andy	28	57	29	104
	7. Victor	47	68	21	45
	Denny	41	60	19	46
	8. Jake	44	59	15	34
	Mickey	62	70	8	13
	9. Phill	36	56	20	56
	Palsan	61	68	7	11

Mean scores by group

	Initial score	Final score	Improvement	% Improved
Girls	41 (range 27–48)	57 (range 50–67)	16	39
Boys	45 (range 28–62)	61 (range 55–70)	17	38
Total group	43	59	16.5	38.5

ANCOVA between initial and final score subject effects. Dependent variable: final test score

Source	Sum of squares	Df	Mean square	F	Significance	Squared
Corrected model	272.939b	2	136.469	7.341	0.006	0.495
Intercept	1290.175	1	1290.175	69.404	0.000	0.822
Initial score	192.716	1	192.716	10.367	0.006*	0.409
Gender	38.010	1	38.010	2.045	0.173	0.120
Error	278.839	15	18.589			
Total	63446.000	18				
Corrected total	551.778	17				

Note: Pseudonyms were used in this report.

* Significant at 0.05 level.

analyze the data in depth in light of the research question, the researcher used axial coding, a set of procedures whereby data were reconstructed based on the research question to determine elements of the children's peer dynamics representing their collaborative engagement with dialectical learning (helping each other, exchanging ideas, co-teaching). As the last stage of data analysis, selective coding was used to choose the core categories, systematically relating them to other categories, triangulating and validating those relations, and filling in categories needing further refinement. During selective coding, initial and final data collected with the ICPC were also examined as part of the data triangulation to capture patterns of the children's collaborative peer dynamics and to compare the proficiency scores with peer interactions. Results of the selective coding appear in the findings of the study.

4. Results

4.1. Finding 1

Initial and final ICPC measures revealed that every child improved his or her skill level during the technology-rich experience. The ANCOVA test reported significant improvement (0.006) of each child's basic computer proficiency skills (see Table 1). Statistically, significance in gender differences is not reported (0.173). This might be due to the small number of subjects (9 for each gender) used in the study.

Overall improvement for all students was about 38.5%, and the genders benefited nearly equally. In one case, the child's improvement (Andy's) exceeded 100%. In addition minimal improvement was shown by two boys (Palsan and Mickey), whose basic proficiency skills were already "fluent," marked highest with 4 points, from the beginning.

These results seem quite significant, especially given the relatively limited time frame of the study (seven weeks) and the similarly limited time students spent in the technology-rich environment (2 h per day). As teachers in the Ameritech Classroom had previously observed in the aforementioned studies conducted by Tiene and Luft (2001a, 2002b), students can develop technology skills at a far more rapid pace in a technology-rich setting than they would in a typical classroom. This appears to be especially true for these 5- to 6-year-old children, who seemed developmentally ready to work with technology.

Overall, the boys' proficiency levels were slightly higher initially (41 versus 45). Even though not statistically significant, the proportion of improvement among the girls was slightly higher; so they benefited as much as the boys did by learning in the technology-rich classroom. Finally, children with weak computer skills benefited tremendously from being in the technology-rich classroom environment. The two children (Ann and Andy) with the lowest initial scores on the ICPC demonstrated the greatest degree of improvement by the end of the experience.

Among the 20 proficiency skills, three characteristics specifically involved peer-interaction behaviors: (a) be able to help peers by showing or pointing out (using a limited number of simple words); (b) be able to help peers by explaining (using a limited number of simple words); and (c) be able to experiment with the program with partners, peers, and adults. These three proficiencies were considered parts of the children's collaborative engagement and learner behaviors. Table 2

Table 2
Changes in peer interaction behaviors

Pairings	Be able to help peers by showing/pointing out		Be able to help peers by explaining		Be able to experiment with the program with partners, peers, or adults		
	Initial	Final	Initial	Final	Initial	Final	
Girls							
1. Ann	Not obs	Fluent	Not obs	Emrg	Not obs	Emrg	
Sangi	Not obs	Emrg	Not obs	Emrg	Not obs	Emrg	
2. Hyeemun	Emrg	Fluent	Emrg	Fluent	Need ast	Fluent	
Suna	Emrg	Fluent	Emrg	Emrg	Emrg	Emrg	
3. Joanna	Emrg	Fluent	Emrg	Fluent	Fluent	Fluent	
Marsha	Fluent	Fluent	Fluent	Fluent	Emrg	Fluent	
4. Sasha	Emrg	Fluent	Emrg	Fluent	Emrg	Fluent	
Mandy	Need ast	Fluent	Need ast	Fluent	Need ast	Fluent	
5. Annie	Emrg	Fluent	Emrg	Emrg	Emrg	Fluent	
Boys							
Al	Emrg	Fluent	Need ast	Emrg	Emrg	Fluent	
6. Augustine	Not obs	Fluent	Not obs	Emrg	Not obs	Fluent	
Andy	Not obs	Fluent	Not obs	Emrg	Emrg	Fluent	
7. Victor	Not obs	Fluent	Not obs	Fluent	Fluent	Fluent	
Denny	Emrg	Fluent	Fluent	Fluent	Emrg	Fluent	
8. Jake	Emrg	Fluent	Emrg	Emrg	Emrg	Fluent	
Mickey	Fluent	Fluent	Fluent	Fluent	Fluent	Fluent	
9. Phill	Emrg	Fluent	Emrg	Emrg	Emrg	Fluent	
Palsan	Fluent	Fluent	Fluent	Fluent	Fluent	Fluent	

presents how each child changed in these particular behaviors between initial and final measures. During the initial measure, both boys and girls exhibited various levels of showing or pointing out directions along with using a limited number of simple words with peers to explore software programs. As shown by the final measure, all children except one (Sangi) fluently engaged in helping peers by showing or pointing out directions, using a limited number of simple words to explore software programs, for example, “This” when pointing at an error sign to change pages; “Click this, click, click” when touching the arrow symbol on the screen.

At the beginning of the technology-rich classroom experience, both boys and girls exhibited various levels of using words only to help peers. During the final measure, girls exhibited a higher fluency in using words only to help peers. More boys exhibited an emerging level of using words only with their peers (e.g., “How do you make it disappear? Click that, not that one, hum... hum... the square thing. Yah. Yah.”).

As indicated in Table 2 “Be able to help peers by explaining” seemed to be a more difficult proficiency for these children to master than “Be able to help peers by showing or pointing out.”

At the beginning of the technology-rich classroom experience, girls exhibited varied levels of proficiency in experimenting with programs with peers or adults. In contrast, most boys engaged in this kind of behavior from the beginning. Toward the end of the period, both gender groups exhibited fluency in experimenting with various computer software and hardware programs with peers and/or adults.

4.2. Finding 2

Table 3 presents the ICPC measures in pairs as well as a brief qualitative description of each pair's pattern of peer dynamics.

As indicated in Table 3, a pair who had frequent absences (pair 8), pairs who often used two different computers side by side (pairs 4 and 7), or pairs who simply shared the computer with serial turn taking (pairs 1 and 2) did not exhibit rich collaborative interactions within the pair; that is, they did not exhibit or seldom exhibited behaviors like helping each other, exchanging ideas, or co-teaching.

In the case of pair 5, the two children experienced no conflict sharing the computer in terms of serial turn taking but exhibited limited co-exploring or co-teaching. Often, Al sat next to Annie, looking at the computer screen and observing what she was doing. Al's limited English proficiency might have inhibited their dialectical learning. In the case of pair 1, Ann was identified as a learner with special needs in vision and learning delay. Even though she and her partner (Sangi) engaged in little peer teaching, program exploration, or map construction on the screen together, Ann achieved the second highest improvement among the children as measured by the ICPC. Time spent exploring simple functions by herself might have contributed to her improvement.

Mickey, who began and ended with the highest scores on the ICPC, exhibited a different type of peer dynamic. Because of his partner's frequent absents, he engaged in frequent interaction with other children and assistant teachers; often he enjoyed teaching his discoveries to others:

Mickey: (As he explored the *Golden Books Encyclopedia for Kids*, listening to the story with some background music, he was dancing. He gave his headphones to Danny to enjoy the music, too.) Listen to this! I found it out.

Mickey: (saying to one of the teachers) Do you know the pyramid? You need to listen to this. It tells you everything [about it]. It [this program] has real cool music too [that goes with the exploration of the pyramid]! I can still hear it in my mind.

As discussed by Crook (1998), Mickey's self-initiated social behavior of letting others know what he knows seemed to contribute to his continuous improvement.

Pairs 3, 6, 9, Mandy, and Victor exhibited frequent peer-mediated and dialectical co-teaching. Pair 2 exhibited peer dynamics behaviors requiring careful interpretation. The following findings detail the children's dialectical peer teaching and learning.

4.3. Finding 3

According to Rubin and Hebert's (1995) study, one of the most effective methods of teaching involves learners teaching other learners. Collaborative peer teaching is regarded as highly ef-

Table 3
Characteristics of pairs

Pair 1 – Ann and Sangi: These children performed below average on both measures. They experienced constant conflict in sharing the computer, which took the form more of serial turn-taking than interacting with each other using the tool. Ann was identified as a learner with special needs in vision and learning delay. Even though she scored below average scores on both measures of ICPC, she achieved the second highest improvement among the children. Sangi began and ended with below average score in ICPC

Pair 2 – Hyeun and Suna: This pair experienced constant conflict in sharing the computer, which took the form more of serial turn taking than interacting with each other using the tool. Instead, they sought peer interaction without the computer, using other materials and classroom facilities similar to their regular classroom environment. They both enjoyed drawing on paper. Hyeun started with average scores and ended with below average scores on the ICPC. She enjoyed personal story journal writing along with illustration of her stories. Suna started with above average scores and ended with below average scores on the ICPC. Most of time Suna's play with computer entailed nonpurposeful clicking

Pair 3 – Joanna and Marsha: Most of the time they played with the same software (KidPix) doing activities that involved shared interests, such as drawing or finding mermaids and making them move on the screen. Among the girls' pairs, Pair 3 exhibited the most positive peer interaction with some level of peer-mediated teaching behaviors by Joanna. Joanna started with above average scores and ended with below average scores on the ICPC. Marsha started with above average scores (but lower than Joanna's) and ended with below average scores (yet, higher than Joanna's) on the ICPC. Marsha improved more than Joanna

Pair 4 – Sasha and Mandy: Each child preferred to play with the computer by herself, seldom working together. Because extra computers were available next to their computer table, they usually worked on the computers individually. Mandy often interacted with Victor, working together on small-group mapping projects on both the computer and paper. Sasha started and ended with above average scores on both measures of the ICPC. Mandy started with below average scores, earning the second highest change in scores among girls, and third highest in the group on the ICPC

Pair 5 – Annie and Al: Most of the time Annie controlled the computer, and Al sat next to her looking at the computer screen. Al used very limited English. When he started the kindergarten, he had been in the US less than a week. Annie started with above average scores and ended with average scores on the ICPC. Al started and ended with below average scores on the ICPC

Pair 6 – Augustine and Andy: Sharing the computer was as easy for them as playing with other materials, tools, and toys. Usually Augustine attempted to initiate new exploration, often teaching Andy what to do or how to do it. Andy followed Augustine's directions. They frequently exhibited peer-teaching behaviors. Augustine started and ended with below average scores on both measures of the ICPC. Andy, a year younger than others in the group, started with the lowest score on the initial measure and ended with below average scores, but achieved the highest improvement among the children on the ICPC

Pair 7 – Victor and Danny: Most of the time they used two computers because an extra computer was available nearby. They always sat side by side, but little interaction occurred between them. Victor also frequently interacted with Mandy to work on small-group mapping projects on computer and paper. Victor started with above average scores and ended with second highest score on the final ICPC. Danny started with below average scores and ended with above average scores on the final ICPC

Pair 8 – Jake and Mickey: Because of Jake's frequent absence, they did not play together all the time. Jake started with above average scores and ended with average scores on the ICPC. Mickey started and ended with highest score. Because of his partner's frequent absence and his propensity to enjoy working with adults (assistant teachers), he engaged in frequent interaction with the teachers, who assisted his inquiry. He also enjoyed sharing and teaching what he newly discovered with adults by playing with the computer and new software and hardware

Table 3 (continued)

Pair 9 – Phill and Palsan: This pair played and interacted well together without a conflict in sharing and experimenting with the computer. Both frequently initiated new exploration. Usually Palsan taught Phill what to do or how to do it. Phill followed Palsan's directions. Often, they exhibited peer-teaching behaviors. Phill was a year younger than others in the group. Even though Phill earned below average scores on both measures of the ICPC, he showed the second highest improvement among boys, fourth highest in the entire group. Palsan started and ended with second highest scores on the ICPC.

fective. The children fluently asked questions and naturally assisted one another in the technology-rich learning environment. In the collaborative peer-teaching situation, the children's conversation showed a sense of self-confidence as shown in the following example involving pair 9 (Phill and Palsan), working and playing with map-making software.

Phill: Which way do I go, Palsan?

Palsan: You go south and I'm going around in circles.

Joanna: How do you save it? (Joanna wants to save her new map in her electronic folder.)

Victor: I can help you. Go to Save. Go to your folder. Then, go to the box. Put in the name. Type it. And click Save.

Joanna: I know how to do it NOW!

Hyeemun: (showing Phill how to change font and font size) See, you can change the words like this! [by clicking on different font lists and numbers for different sizes]

Phill: Hyeemun found this! It is so cool.

Hyeemun: I wrote my phone number ###-###-#(she typed her home phone number with font size 48).

Andy: I don't know how to shut down.

Phill: (approaching Andy, pointing to the X box—exit button—on the top corner of the right side on the screen.) Click this.

4.4. Finding 4

Each pair exhibited a unique style of interaction as they worked together. A pair whose levels of computer proficiency differed but who shared similar interests (e.g., playing with the same software programs) worked very well in their hardware sharing (e.g., computer, digital camera, video camera, and AlphaSmart). Interaction in pair 9 serves as an example:

Palsan: Make it bigger.

Phill: (made the screen bigger, dragging down the cursor from the top to the bottom right side of the dotted box) That's cool!

Palsan: Now play.

Phill: (following Palsan's direction, clicked on a play button) Oh! Ha, ha! Look!

Palsan: Go to the eraser. Can we make it bigger? I need to try, Phill.

Phill: (gave the mouse to Palsan without hesitation, waited for 2 minutes watching Palsan playing) Can I have my turn now?

Palsan: (gave the mouse to Phill without any hesitation)

Phill: There is a lot of stuff we can do on [the computer] together. We like to do KidPix and draw together.

Teacher: How did you know you could erase the picture?

Phill: We tried it out.

They played and interacted well together without conflict, sharing and experimenting with the computer, both frequently initiating exploration. When Palsan taught Phill what to do or how to do it, Phill followed Palsan's directions. Often, they exhibited peer-teaching behaviors. Palsan dominated, giving verbal directions to his partner as his partner played with and explored the program. Both of them took balanced turns without conflict as they shared the computer during the free playtime each day. Their peer dynamics were consistently exploratory and experimental. Even though Phill was one year younger than his partner and scored below average on both measures of the ICPC, he achieved the second highest improvement among boys, and fourth highest in the entire group. Palsan began and ended with second highest measure of basic computer proficiency skills.

Other pairs, such as pair 3 (Joanna and Marsha), had different computer proficiency level scores; however, they shared similar interests and exhibited high-level meta-cognitive thinking skills as their strategy (e.g., "Save it in your head"; "Put them in a school group").

Sue: (teacher): How do you decide who uses the mouse?

Joanna: We don't decide. We just do it.

Marsha: We need a couple of these [fish].

Joanna: Put them in a school group.

Marsha: What should we call it? Let's call it 'Seal Mermaid.'

Joanna: Let's call it whatever we want in our folder.

Marsha: I'll call it 'Seal.'

Joanna: Save it in your head. [So that we will use the name when we save the drawing into the electronic file.]

Joanna, who at the beginning exhibited proficiency more advanced than Marsha, taught her peer to use mental tools (categorical and memory-storing thinking skills) as a strategy. This is a good example of Vygotsky's (1978) notion of collaboration with more capable peers (p. 86), yet the progress this particular pair made on the final ICPC measure was somewhat limited compared to that of Pair 9. Most of the time Joanna and Marsha played with the same software (KidPix), engaging in the same kind of activity. They shared similar interests, such as drawing or finding mermaids, which they enjoyed animating on the screen. In contrast, Marsha was more interested in clicking and moving on to the next image. Marsha, whose proficiency was lower than Joanna's

at the outset, was often interested in simply looking at diverse animated images on the screen as she clicked the mouse or button. Marsha's behavior often seemed to frustrate Joanna, who sat next to Marsha, giving her brief suggestions (e.g., "Click the other one. You have to name it") and waiting for her turn to play. Boredom with her partner might have contributed to Joanna's final score on the ICPC, which indicated little improvement.

4.5. Finding 5

Kindergartners who (a) were new to the computer as a tool for learning and playing, (b) started with average or low computer proficiency and ended with average or low proficiency, and (c) shared the computer with a peer in the form of serial turn taking tended to show nonmindful clicking behaviors as their play pattern. Pair 2 (Suna and Hyeun) began at a low level of computer proficiency and ended with average progress compared with other children. In the technology-rich classroom, they experienced constant conflict in sharing the computer, seldom engaging in peer-teaching and learning. Their peer dynamics involved one child's clicking and the waiting child's asking for her turn as shown below:

Suna: (simply and nonpurposefully exploring the program by clicking buttons on the KidPix screen)

Hyeun: (watching Suna for a while) Hit the letters. Go to this place (pointing at the picture).

Suna: (tries Hyeun's suggestion and quickly moves on to nonpurposeful clicking motion, simply looking for what might be shown as result of clicking)

Hyeun: (waiting less than 2 minutes) Can I have my turn?

Suna: No, I've just started (more clicking).

Hyeun: (About 3 minutes later, Hyeun had her turn to play with the computer. She alone played KidPix games.)

Suna: (looked at others and soon left the station to another area)

4.6. Finding 6

In peer teaching, also known as peer-mediated teaching (Utley, Mortweet, & Greenwood, 1997), students serve as instructional assistants for classmates and other children. A learner's peer-teaching role can be direct (e.g., tutoring) or indirect (e.g., modeling, encouraging) in nature and can focus on academic and interpersonal outcomes (Maheady, Happer, & Mallette, 2001). Unique peer dynamics shown in the children's conversations indicated their use of multiple perspective taking and reflective self-assessment as they worked in the technology-rich learning environment. The following serves as an example:

Mandy: (trying to draw a map on the computer exactly as she had drawn it on the paper based on her observation of the sidewalk outside)

Victor: (drawing a map on the computer totally different from what he had drawn on paper)

Mandy: (looking at Vic's computer screen and talking to him) Victor, you put grass on. You can move them [roads and cars] any way you want to go.

Victor: (busy adding more roads and houses on the imaginative map.

Frequently, he deleted some houses on his map, relocating them to different places)

Mandy: Oh! I had no idea how to do it! (Mandy learned how to delete images/items on the screen by watching Victor, who was working on his map)

Mandy: (giving Victor suggestions) Victor, if you make it yellow, it shows you the inside.

Victor: Oh, I didn't know that. Now I know.

Later, during the reflection time at the end of the day,

Augustine: (talking about erasing images)

Joanna: I learned how to erase the picture that you do not want anymore.

Victor: I used the delete key to erase the stuff. I made a map of mine that has 100 schools, buildings, and roads. It was so...cool. I explored. I got into it. Yellow. I can take a closer look (based on what he had learned from Mandy).

Mandy: Victor and me, we were trying to finish the map of the sidewalk, grass, trees, and cars.

Mandy's behavior exhibited peer-mediated teaching. She was capable of using multiple perspectives in observing the work of peers on the computer and sharing some meaningful, useful, and appropriate technical ideas and suggestions with her peer even though he had not asked for it. Victor, Mandy's peer, listened, tried what she suggested, and then immersed himself in new learning and exploration. In a Vygotskian sense, Mandy acted as the catalyst for Victor's growth in his independent work with the software. At the same time, Mandy also focused on what her peer could do that she could not (self-assessment, critical thinking, deep learning) and tried new ideas based on the observation, expressing the new discovery she had made.

5. Discussion

Vygotsky's (1978) notions of collaboration with more capable peers and friendship as a significant factor in collaboration and peer dynamics (Crook, 1994, 1998; Roschelle & Clancey, 1992) are important considerations in pairing or grouping children. The dynamics of pairs 9 (Palsan and Phill) and 3 (Joanna and Marsha) clearly support these two principles. According to Vygotsky (1978) social contexts are essential in children's learning. Children can perform ordinary tasks independently and more complex tasks in collaboration with more capable peers or adults. At the outset of this study, Palsan and Joanna were more capable peers in terms of computer proficiency, exhibiting higher levels of representational skills. Enhancing their ability to collaborate, their peer dynamics advanced their learning with computers more so than the other pairs of the children (for example, Pair 2, Hyeun and Suna). When pairing children in a collaborative learning environment, particularly a technology-rich learning environment, teachers need to as-

sess children's computer proficiency carefully and assign pairs in which peer teaching and learning dynamics would occur naturally.

Teachers in a technology-rich classroom must also recognize that more capable peers may not always be intellectually challenged enough by the peer whose capabilities are still in an emerging stage. Sometimes, their friendships may delay growth because of "comfort zones" based on shared interests. Pair 3 (Joanna and Marsha), uninterested in deep exploration, simply returned to their familiar "favorite" program.

When Palsan and Joanna, who earned high scores on the initial ICPC, used computers individually, they both exhibited much more complicated and self-challenging exploratory behaviors than they did with their assigned partner. When they had a chance to use the computer alone, Marsha and Phill, who earned low scores on the initial ICPC, practiced new skills that they learned from their peers and explored new things on their own. Pairing children to share a computer is constructively meaningful and effective on some level and to a certain degree; thus, providing balanced opportunities for sharing and individual work is an important consideration.

To gain a deeper understanding of Suna and Hyeun's case, consider the theoretical notion of "thought-producing self," which Fomichova and Fomichov (2000) defined as the mirror of appreciating oneself in a social context. The child must understand that his or her mind produces socially important thoughts. This self-realization influences the way a child defines himself or herself as a person who is able to think, and that thinking, in turn, motivates appreciation and praise for self and for others. The child must know that the work of his or her mind – thinking – is autonomous, appreciated, acknowledged, and respected. By definition the thought-producing self is realized in the child only if he or she is able to generate ideas with a relatively high social and cognitive significance. Intensive nonpurposeful use of computers (e.g., nonmindful clicking) by the child before the realization of his or her thought-producing self may prevent him or her from developing as a creatively thinking person.

The computer as a processor of information can impede and restrain the child's cognitive development. In order for computers, which have become a key element in the new information society, to promote, not interfere with, the cognitive development of human minds, the child must become a creatively thinking individual. Before we introduce the tool to young children, we need to make sure that they learn autonomy and develop the ability to see themselves as creative thinkers. This consideration is critical, especially for children who exhibit nonmindful clicking behaviors. The role of an adult in the technology-rich classroom is to guide young children to discover their "thought-producing selves" in collaborative peer teaching and learning contexts.

In contrast, Suna and Hyeun, who worked very well together in their regular classroom, particularly enjoyed drawing together. Representational skills shown in their drawings were very well formed and rich; however, they always experienced conflict in sharing their computer in the technology-rich classroom, seldom working together exploring and doing activities (e.g., drawing a map on the computer, writing stories with drawings on the computer, or exploring new software programs). In the middle of the technology-rich classroom experiences, Suna and Hyeun changed their pattern of working together, often moving to another open table without computers and drawing maps on paper. One day when they sat side by side engaging in free drawing, Hyeun put Suna's and her drawings together and said, "Oh! Look! We can put our pictures together and make a big picture of a house." This kind of collaborative behavior was frequently observed in

their regular classroom setting. Months before the technology-rich classroom experience, each of these two children had already discovered and developed a “thought-producing self” through creative drawing, map making, and designing images using conventional but fully controllable tools, such as paper, pencils, markers, crayons, clay, and construction paper. Sharing materials and collaborating were much easier and more natural for them with those tools. In one conversation with the researcher during the seven-week period, these two children clearly expressed their preference for drawing on paper over doing so on a computer screen.

Suna: [We like drawing] on paper because it is easier. When you mess up on paper, it is easier to fix it.

Hyeun: On paper, your pictures turn out better. On computer, they make spots that you don't want.

The new learning environment with somewhat unfamiliar and physically limiting tools, such as computer hardware and software, made it difficult for them to share and work together. In this regard, the technology blocked or restrained the continuation of their rich collaborative and creative interactions. They were unable to realize their “thought-producing selves” at the beginning of the technology-rich experience; however, the “thought-producing self” in each child eventually found a way to overcome the limitations of her experience, supporting collaborative, creative, and meaningful learning experiences by situating them in a physical setting with elements similar to those of their regular classroom. Hyeun and Suna's learner behaviors clearly indicated the importance of preserving and continuously enhancing their learning styles, demonstrating the importance of maintaining a balance in the classroom between conventional and high-tech learning tools.

Mandy and Victor's peer teaching and self-assessment behaviors serve as a clear example of Biggs' (1987, 1993) notion of deep learning with critical thinking:

Mandy: What can teach my friend Vic? I think I can help him in what he is trying to do.

Victor: What is it that I don't know but Mandy can teach me?

These two children actively made discoveries in a learning context involving technology, significantly influencing the way they perceived tools, events, and ideas. Bolstering each other's new technological skills with critical and reflective deep learner behaviors, these children became autonomous learners (Fleer, 1999; Newman et al., 1997). Without realizing it, they were already deeply engaged in a socially and intellectually powerful interdependent learning community. Of all 18 children Mandy improved the most between the initial and final measures of her computer skills. Victor began with above average skills and ended with second highest final score on the ICPC. Their initial and final scores on the ICPC positively correlated in a qualitative sense with the dialectical richness of their learner behaviors.

6. Conclusion and implication

The children were fluent in asking questions and naturally assisting one another in the technology-rich learning environment, each pair exhibiting a unique style of interaction as they worked together. A pair whose computer proficiency differed but who shared similar interests worked very well, illustrating Vygotsky's dialectical constructivist perspective on peer teaching

and learning characteristics. More capable children, however, were not always sufficiently challenged intellectually by peers whose capabilities were still in an emerging stage. Sometimes their friendship inhibited growth because their shared interests kept them in their “comfort zones.” Friendship, a significant factor in collaboration and peer dynamics, must be carefully considered with each child’s level of self-realization of the autonomous thought-producing self. Pairing children to share a computer is constructively meaningful and effective on some level and to a certain degree, but providing balanced opportunities for individual and collaborative work is an important issue for children who perform at different levels of computer proficiency.

Some children’s conversation exhibited deep learner behaviors with a sense of self-confidence, critical thinking, multiple perspective taking, and reflective self-assessment as they participated in the technology-rich learning environment. Their initial and final measures on the ICPC positively linked with their dialectically rich learner behaviors. A pair who experienced frequent absences or often used two different computers side by side or simply shared the computer with serial turn taking did not exhibit dialectically rich collaborative peer dynamics. These were the pairs in which partners began and ended with below-average basic computer proficiency. Thus, assessment and rearrangement of the learner pairs are necessities for effective peer dynamics in a technology-rich learning environment.

Young children who were new to the computer as a tool for learning and playing and exhibited low-level proficiency spent most of their free playtime engaging in nonpurposeful clicking of images and buttons on the computer screen. Teachers need to make sure that young children learn how to act autonomously and to see themselves as creative thinkers (i.e., thought-producing selves) before exposing them to a technology-rich learning environment as well as during the time they engage in that kind of environment. In some cases, young children may have formed images of thought-producing selves in the conventional learning environment but may not easily engage that mindset in a technology-rich learning environment. Adults in such an environment need to assist children thoughtfully in exercising their own thought-producing selves in the new learning environment. The physical learning environment must provide a balance of conventional learning tools and high-tech tools; more research is necessary on the need for such a balance.

In children’s peer interaction, humorous conversations occurred as they observed each other’s work. For example:

Sangi & Palsan: (playing with KidPix, sitting side by side, using different computers)

Sangi: Cool! I can move the bunny rabbit.

Palsan: (glancing at Sangi’s without saying a word)

Sangi: (continuing to draw strawberries and ice cream)

Palsan: Your picture makes me hungry. I could eat your computer!

Sangi: Ha! Ha! Ha! You are really funny!

Humor in the peer dynamics of young children in technology-rich classrooms also deserves careful investigation.

Shade (1999) argued, “It is important to note that it takes time for teachers to become accustomed to new technologies. When first introduced, the chalkboard went unused for many years until

Appendix A (continued)

Task	Fluent		Emerging		Needs assistant		Not observed		Notes	
	Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final
17. Be able to experiment with the program with partners, peers, and adults										
18. Be able to use backspace and delete keys to edit										
19. Be able to use letters on the screen as a key to go to certain page										
20. Be able to read words on the screen before playing or interacting with the program										

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