Parents as Learning Partners in the Development of Technological Fluency

IJLM

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Keywords
Families
Informal learning
Interest, learning ecology
Intergenerational learning
Technological fluency

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doi: 10.1162/ijlm.2009.0021

Volume 1, Number 2

Abstract

This paper presents research on parent support of the development of new media skills and technological fluency. Parents' roles in their children's learning were identified based on interviews with eight middle school students and their parents. All eight students were highly experienced with technology activities. Seven distinct parental roles that supported learning were identified and defined: Teacher, Collaborator, Learning Broker, Resource Provider, Nontechnical Consultant, Employer, and Learner. The parents in this sample varied in their level of technological knowledge, though in every family at least one parent worked in the computer industry as an engineer or designer. The paper presents the approach used to identify these roles, the coding system used, and examples of each role across the cases. The diversity and density of roles played by parents for individual students are also quantified. Findings indicate that for these eight learners parents play significant roles in supporting creative technologically mediated activities. The findings highlight the importance of understanding family-based learning relationships when considering pathways to early expertise with new media.

Introduction

> "My idea was just to give him something simple. He can obviously do much more complex stuff. But I thought I'd give him a really simple Flash project."
>
> *Father of a 13-year-old animator*

> "They send out these little announcements occasionally about robotics—I knew Craig would be interested so I just emailed back."
>
> *Mother of a 13-year-old robotics aficionado*

Broad surveys of children's use of media paint a portrait of youth increasingly immersed in technologically mediated activities. Time is spent online for game play, exploration of personal interests, social networking, and homework help (Lenhart and Madden 2005; Rideout, Roberts, and Foehr 2005). Digital technologies also offer children and adolescents rich opportunities to design and create artwork, stories, games, animations, interactive robots, and other expressive or documentary artifacts. These production-oriented activities can introduce students to the computational power of computing tools and begin to convey concepts such as algorithmic thinking that are thought to be important components of technological fluency or digital literacy, typically defined as the ability to adapt computing tools creatively to learn and contribute to one's community (National Research Council 1999; Wing 2006; International Society for Technology in Education 2007).

Surrounding these activities are "cultures of participation" (Jenkins et al. 2006) or "affinity spaces" (Gee 2008) where young people share their work, receive feedback, and expand their social networks. Informal collaborative relationships can develop as learners share knowledge and codevelop interests. Some researchers have suggested that participation in these informal collectives nurtures important 21st-century capacities such as the willingness to engage in collaborative work, knowledge of how to manage information, self-direction of one's own learning, capitalizing on opportunities for distributed cognition, and the building of collective intelligence (Jenkins et al. 2006). The ability to author new-media artifacts—including selecting tools, remixing existing elements, and developing new genres of presentation (e.g., blogs, podcasts, online comics)—is increasingly recognized as an emerging component of digital media literacy along with the capacity to critique and navigate diverse representations of information (New London Group 1996; Jenkins et al. 2006; Ito et al. 2008).

Though these cultures of participation are highly motivating for the youth who participate, concern is growing that they are not equally accessed and that differential access or "participation gaps" may translate into inequities in opportunities to learn (Jenkins et al. 2006). The term *digital divide* increasingly reflects a multidimensional construct involving inequities in how people use computing tools and how skilled they are (DiMaggio et al. 2004; Hargittai 2008). A number of studies suggest that the teens who routinely use their computing savvy to build, create, author, or design expressive artifacts or tools are the exception rather than the rule (Barron 2004; Livingstone and Helsper 2007; Lenhart and Madden 2005). Quantitative studies with large samples looking at activities such as programming, robotics, computer assisted design, or using a computer to model or simulate complex phenomena show differences in rates of participation as a function of gender or level of home access (Barron 2004). In a U.K. study of a representative sample of 9- to 19-year-olds, significant differences in the breadth of Internet activities were found as a function of age, gender, and socioeconomic status (SES) (Livingstone and Helsper 2007). The authors identified four profiles of use. "Basic users" used the Internet mainly to seek information, "moderate users" went beyond information seeking to use the Internet for entertainment and communication, and "broad users" had a more expansive repertoire that included instant messaging and downloading music. Only the "all rounders" group used the Internet for new media production activities. Overall, 27 percent of their sample fell into this group. In a set of analyses designed to look at the factors that predicted breadth of experience, the authors found that frequency of use and the number of years online accounted for variability but so did SES and gender. Lenhart and Madden's (2005) telephone survey of a representative sample of U.S. teens found that about 20 percent of Internet users had remixed content found online and about half of teens had uploaded personal artifacts such as photos, videos, or stories.

Similar patterns of differential use were identified in a comprehensive ethnographic study carried out in the United States (Ito et al. 2008). The authors found that youth primarily used Internet tools as a way to extend their social activities through various forms of "hanging out" online. Fewer youth engaged in exploratory design activities the authors labeled as instances of "messing around," activities that required access to tools coupled with the freedom and autonomy to engage in self-directed learning. On rare occasions the authors found that casual tinkering and experimentation would lead to "geeking out," a more committed form of production signaled by an intense commitment to a media genre or type of activity. In addition to time and tools, geeking out was always accompanied by access to a knowledgeable community.

Together these studies suggest that only some youth are becoming new media producers. The learning environments that support access to these empowering uses of new media, which are thought to be critical for the development of new media skills, dispositions, and knowledge, need to be better understood. Though the studies reviewed above point to the importance of physical access to tools, they also suggest that access to knowledgeable peers or mentors can be key. The present research report contributes to the theoretical project of conceptualizing learning environments that support the development of empowered and generative uses of technology by focusing on the ways that parents instrumentally support the new media production activities of their children.

Overview of the Current Study and Rationale for Design

The analyses presented in this report are guided by sociocultural and ecological perspectives on development generally (e.g., Lewin 1954; Bronfenbrenner 1979; Cole 1996) and more specifically by a learning ecology framework (Barron 2004, 2006). This framework conceptualizes the learners and their multiple life settings as the appropriate unit of analysis for understanding individual differences in learning or interest development and recognizes the transactional nature of learning. The present report seeks to describe the nature of social interactions that surround and support learning (Vygotsky 1978; Lave and Wenger 1991) and to foreground how learning occurs within activities supported and transformed by material resources, technologies, and ideas.

The goal of describing learning resources that support engagement in production activities led to a qualitative study design that used a purposeful sampling strategy. Rather than randomly sampling learners, middle school students who were highly engaged in fluency-building activities were identified. Sampling at the extremes of a distribution is recommended when rich detail is needed about an understudied phenomenon (Patton 1990). The research literature suggests that a minority of teens engage in high levels of production activity, and although social networks are acknowledged to be important, little is known about the learning processes within them. The strategy of sampling learners who are at the upper end of the distribution in their production activities allows researchers to identify elements of their learning histories and practices that contributed to their accomplishments. This in turn allows the identification of factors and design principles that support a broader range of learners. Scholarship in the study of teacher expertise has productively followed this approach by selecting for study the rare but expert teacher. The study of idealized practice is undertaken in order to identify what is possible (Wineburg and Wilson 1991). By analogy, the goal of the present research is to describe some of the social practices that support new media production skills, with the eventual aim of inspiring the design of environments that can bridge divides. The prominent role of parents in supporting children's new media production skills was unanticipated when the study began. The importance of parental support became apparent through a grounded theory approach (Charmaz 1995), and the analysis reported in this paper expands the understanding of family practices that support learning.

The criterion for an adolescent's inclusion in the study was that he or she was involved in developing at least one project on his or her own time outside school hours. Recruited adolescents included those who sustained activities involving the use of computers and the Internet to create digital artifacts such as interactive programs, games, music, art, Flash animations, robots, or 3D models. Learning histories were obtained through parent and child interviews. The qualitative data set afforded several options for the analysis of case material and presentation of findings. This report provides brief case portraits and delves deeply into one aspect of the learning ecology, namely, forms of support within the parent-child relationship. Though this choice prevents the communication of the detailed nuances of each learner's learning biography, aggregating across cases allows for the development of categories that may be useful to other researchers who want to study the role of social networks in supporting production activity.

Research Questions

Two questions guide the analysis:

1. What types of parent roles can be identified that instrumentally support adolescents' learning and engagement in fluency-building activities such as robotics, movie making, and programming projects?
2. How do parent roles vary for individual children in type or frequency?

The Role of Parents in Nurturing Expertise

Empirical work on the social grounding of cognitive development has documented the varied ways that caregivers and companions guide participation in culturally valued activities and practices (Rogoff 1999; Gauvain 2001). Parents tacitly or explicitly structure learning opportunities long before formal schooling begins in order to nurture language development (Heath 1983), early literacy skills (Sénéchal and LeFevre 2002), scientific discourse practices and concepts (Ochs 1993; Crowley, Callanan, Tenenbaum, and Allen 2001; Fender and Crowley 2007; Palmquist and Crowley 2007), early number skills (Saxe, Guberman, and Gearhart 1987), competency with technology (Plowman, McPake, and Stephen 2008), and musical talent (Bloom 1985). Parents indirectly influence learning by providing particular toys or media and by arranging social activities or excursions. Provision of materials that match a child's interest can encourage sustained exploration of a topic that can develop content knowledge (Leibham et al. 2005). Parents more directly contribute to learning by engaging in co-activity, such as playing board games or reading aloud to children. In these contexts, explanations can be provided spontaneously or in response to questions, the child can learn through observing, and performance can be scaffolded and supported within the child's current zone of proximal development (Vygotsky 1978). Intimate relationships also provide opportunities for communicating the value of specific activities, encouraging a sense of self-efficacy, and modeling productive dispositions (Zeldin and Pajares 2000).

Research has found that once school begins, parents mediate their child's experience in the classroom by discussing learning events at home, supporting homework completion (Epstein 1995), conveying expectations for performance, and helping to manage time (Drummond and Stipek 2004; Lee and Bowen 2006). Research on these forms of parent involvement has generally shown positive correlations between the amount of involvement and children's achievement in school (Fan and Chen 2001).

In most studies of parent roles in learning, the parents are more expert than the children. The importance of attending to parents' potential roles in supporting fluency building through creative computing activity may not be immediately apparent. Recent characterizations of youth born after 1985 as digital natives and their earlier-born counterparts as digital immigrants (Prensky 2001) might suggest that in general parents typically have little to offer in supporting the development of technological fluency. Empirical work is providing a more complex portrait and suggests that computer use in the home is highly contextualized by the specific family context and mediated by parent interests, knowledge, and values (Kerawalla and Crook 2002; Livingstone 2002). In one comparative study of the use of computers at home and in school the researchers found that parent involvement was rare: 72 percent of parents felt that their child would not like them to be present during computer use, and many felt that their children were competent and did not need their help (Kerawalla and Crook 2002).

Other research suggests that parents may play key roles in their child's technology learning. A large-scale survey conducted with 804 10- to 17-year-olds and their parents highlighted parental influence as an important aspect of computer use among youth living in the Silicon Valley (Rideout, Roberts, and Foehr 2005). Parents were most frequently reported as the source from which teens learned to use the Internet (42 percent), followed by a school class (28 percent), friends or siblings (22 percent), and self-teaching (18 percent). At the same time, 67 percent of the Silicon Valley youth sampled reported knowing more than their mothers about the Internet, and 50 percent reported knowing more than their fathers. This study suggests that parents and children know different things and that in this realm each can be learners as well as teachers. Data from another Silicon Valley–based study of 12th graders indicated that despite uniformly high access to computing tools at home, significant differences existed in history of computing experiences, and these were linked to the learning resources accessed (Barron 2004). For the few girls in this study who had taken a programming class, the influence of a parent or another family member who was a programmer was cited as a motivator in their decision to take the elective class.

Survey-based data collected in the late 1980s from first through fifth graders and their parents living in the U.S. Midwest showed that although parent participation in children's computing activities on average occurred less than two or three times per month, variability in coactivity was positively linked to child activity (Simpkins, Davis-Kean, and Eccles 2005). In addition, parents' ratings of how much they encouraged their child to work or play with a computer outside of school was correlated with the frequency of the child's activity, as was the parents' provision of computer-related resources. These survey data highlight the important roles that parents can play in the development of interest in computing activities. However, the data provide no contextual information about how parent roles emerge and play out in their children's learning. In addition, survey methods are not designed to reveal processes, because they ask participants to indicate frequency of specific behaviors. For example, in the Simpkins, Davis-Kean, and Eccles (2005) study, the provision-of-resource scale had three items. Parents were asked if they had ever bought their child a computer, computer games or software, or computer books or magazines. Similarly, only one item asked about the frequency of parent-child coactivity—how often they "worked with their child on the computer"—and this was rated on a seven-point scale ranging from *never* to *every day*. Plowman, McPake, and Stephen (2008) investigated the more tacit ways in which parents may support their children's technological learning at home. Three quarters of their 24 case-study families expressed a belief that their preschool-age children were "just picking up" their technological competence without parental assistance. But Plowman and colleagues also observed these parents shaping family technology practices by (a) engaging in technology activities in front of their children, (b) furnishing the home with "environmental technologies" that provided many opportunities for learning to take place, and (c) providing distal guidance for their children as the children attempted to operate family equipment independently. These parents failed to recognize how their own interactions with technology provided both behavioral and attitudinal models for their children to emulate. "In the home," according to the authors, "such authentic activities were commonplace and children's learning was characterized as 'just picking it up,' perhaps because parents associated teaching with verbal instruction and discounted the role of showing rather than telling" (p. 314).

The few studies that focus on learning with new technologies at home validate a focus on roles that parents play that support learning. Given that many schools limit the amount of time students spend working with new media technologies, understanding how these technologies are providing learning opportunities at home is critical. The present study allowed for the identification of new parent roles in their children's at-home technology learning. In addition, the study allowed for quantification of the breadth and density of roles for individual learners. The analysis yielded four main observations:

1. *Parents played a variety of roles that were fundamental for the advancement of learners' production activity*. Most of these roles did not require the parent to have greater technical expertise than the child. Parents could collaborate with them, learn from them, broker outside learning opportunities for them, provide nontechnical support for them, or employ them, and these types of engagement furthered learning. Parents also played instrumental roles when they shared their technical expertise through informal teaching processes or provided their children with learning resources such as books or new media tools.
2. *Even among an affluent and technically engaged sample, substantial variability was found in the level of parent engagement as indexed by the breadth and frequency of roles*. Greater breadth of involvement was associated with higher levels of child expertise. Additionally, greater parent involvement was associated with very early onset (prior to age 5) of a child's engagement in new media production activity. Later onset of interest (after age 10 or after elementary school) in production activity was most

often sparked by coactivity with peers rather than parents.

3. *Parents' participation not only provided opportunities for the development of knowledge and skill but offered opportunities for more general socialization of attitudes and perspectives on new media technology*. Through informal teaching moments, parents conveyed their values about technology and innovation. The value parents placed on the technical expertise of their children was marked by parents' investment in out-of-school learning opportunities, equipment, and learning resources including books, software, and hardware. Boundaries between parents' work life and home were on occasion blurred as children engaged in helping with technical tasks or were invited to visit parent workplaces.
4. *Although parent roles were critical resources, learning was also distributed across settings*. Learners took advantage of school-offered electives, joined clubs, attended camps, found online tutorials and examples, participated in affinity groups, read books and magazines, and engaged nonparent mentors in learning partnerships. Interest-driven learning led learners to create and sustain opportunities to further their own development.

Methods

Participants

School Demographics

All participants attended Juniper, a public middle school (sixth through eighth grade) with approximately 875 students located in a primarily upper-middle-class community in Northern California. According to California Department of Education statistics for 2006, 43 percent of students at this school were Caucasian, 34 percent of Asian descent, 8 percent of Hispanic or Latino descent, 4 percent African-American, 1 percent of Pacific Island descent, 1 percent of Filipino descent, and 9 percent other, multiple, or declined to answer. The average parent education level at the school was greater than four on a five-point scale in which one represents *not a high school graduate* and five represents *graduate school*. Several technology electives were available to students, including an introductory programming class, two web design courses, and an engineering course. The engineering course was project based and offered opportunities to carry out engineering assignments where prototypes are built and tested and the results are evaluated. Several computer-related after-school clubs were also available, including a robotics club.

Case Selection

A two-stage process was used to identify six of the eight case-study participants. During the 2004–2005 academic year a survey focused on computer-mediated activities was administered to 75 students who were currently enrolled in either a programming or a web design class at the school. Surveys were administered during class time. Based on students' responses to a set of items that asked for their history of fluency-building activity, 16 students who indicated relatively high levels of engagement with activities such as programming, web design, movie making, or robotics were selected for interviews (see appendix A). The Learning Ecology Interview (described below) asked about the students' use of computers or other technologies across settings in which they spent time. Students who indicated that they had an ongoing technology project were invited to participate in an interview at their home and were asked if they would mind if their parents and other learning partners were interviewed (Parent Interview, described below). Two male students who were not currently in technology classes and did not take the survey were nominated by teachers as candidates for the research because of their extensive experience with technology. These two students participated in the Learning Ecology Interview and then were invited to participate in the larger study, participating in a Parent Interview. The final sample consisted of four females and four males. At the time of the Learning Ecology Interview two of each gender were in eighth grade (four 13-year-olds), and two of each gender were in seventh grade (three 12-year-olds and one 13-year-old girl). Of the males, three were Caucasian and one was mixed-race African-American. Of the females, one was Caucasian, one was of South Asian/Indian descent, and two were of Chinese descent with parents who had immigrated to the United States as adults. All eight students were born in the United States.

Table 1 Case-study participants

	Parents' professions		Age when child first . . .			Lead activities	Breadth of fluency-building activities experienced
	mother	father	used a computer	took a computer-related class	engaged in fluency-building activity		
Jonathan	Interior Designer	Programmer/ Engineer	4	9	6	Programming, web development, database administration	14
Alex	Research Analyst, Market Researcher	Father: Musician, DJ Stepfather: Web Designer	5	12	7	Flash movies and animation	10
Craig	Former Actuary	Mechanical Engineer	2	9	8	Robotics, video production, web design	12
Caleb	Nontech position at tech company	Engineer	2	10	5	Programming, robotics	13
Layla	QA Software Engineer	Computer Hardware Entrepreneur	8	12	12	Online math community, blogging	7
Elizabeth	Publishing Editor	Computer Engineer, System Administrator	7	12	7	Video production, animation, web design	12
Marybeth	Software QA	Programmer	2	13	12	Blogging (web design), instant messaging	14
Stephanie	Patent Lawyer	Software Developer, Manager	8	12	12	Web design, moviemaking, animation	11

Brief Case Portraits

A summary of relevant information about each case-study learner is presented in table 1. Table 2 presents brief case portraits emphasizing each learner's primary activities and his or her participation in more formal learning.

Tools for Data Collection

Learning Ecology Interview

This interview with the student was designed to provide portraits of how the students were using computing technology and learning to use technology across the contexts of home, school, community, and through distributed resources such as books, tutorials, and magazines. This interview also explored the students' sense of what is needed to be good with computers, their plans for learning, and how they saw themselves in relation to technology. A simple diagram illustrating different settings (e.g., home, school, library, church) was used to help focus the children's and interviewer's attention on the important contexts in their learning. Examples of the questions posed to the children are provided in appendix B. Each Learning Ecology Interview was audio-recorded, took place at school, ranged from 23 minutes to 78 minutes in length, and was carried out by one of the four authors.

Parent Interview

The goal of the Parent Interview was to obtain a developmental history that would help confirm the information provided by the case-study learners and to better understand parents' perspectives on their child's activities and how they saw their role in helping their child learn. A secondary goal was to

Table 2 Brief case portraits

Jonathan. At age 13, Jonathan ran two online businesses, was the web developer and administrator for a nonprofit educational organization, and had a computer consulting business. Jonathan considered himself first and foremost to be a programmer and had used his knowledge to build revenue-generating businesses in both the virtual and actual worlds. With the help of his father he began playing with scripting languages and HTML when he was six years old. He took his first formal course in programming online at the age of nine. Jonathan has taken two technology elective courses through school: engineering design and advanced web design. He also participated in multiple after-school clubs with a technology focus, including robotics.

Craig. At age 12, Craig was working on the design of his grandfather's website, participating in a robotics club, and serving in the role of course assistant in his school's web design class. He had a side job videotaping and creating DVD records of recitals for a local music teacher. He participated in a web design summer camp at age eight. At age nine he became an apprentice to a videographer who filmed church services in Craig's church. In this context Craig learned to run each part of a multipart camera recording system and became familiar with the underlying technology and how to keep it tuned. In middle school Craig took programming and web design classes. Craig recalls being fascinated by computers long before school began and that he had the chance to observe what computers could do as he sat on his father's lap while his father worked. His interest in robotics was sparked at age eight during exploration of the LEGO Mindstorms robotics kit, supported by his father.

Alex. At age 13, Alex was an aspiring game designer whose lead computing activity involved creating animated movies using Flash. Alex began tinkering with computers with his stepfather and "started getting into it" around age six or seven. At home he had a computer in his bedroom where he spent several hours a week working on his projects. Alex reported having multiple projects in the works at any one time, at various stages of completion. During seventh grade Alex took a course in programming. Alex considered himself an artist and is involved in both drawing and music. His interest in creating digital media flowed from his long-standing passion for drawing, his experience with piano and trombone, and his enthusiasm for computer games. His animated movies often included both his drawings and music. He had built extensive digital libraries of his original graphic images of planets and spaceships.

Caleb. At age 14, Caleb had coached the school's robotics club and had worked as a website consultant for an international education project between his school and a school in China. He had maintained an ongoing project for three years that involved designing an environment that could help children learn about robotics. His interest in robotics was encouraged by his father and began during early elementary school. Caleb had established relationships with several adults in the technology community, including NASA engineers and friends who run technology companies. Caleb viewed himself as a contributing member of a "live" adult community of technology experts working on open-source code. Caleb took the engineering design course offered at his school but did not take web design or programming electives because he felt he already knew the content. He attended several technology camps focused on programming or robotics.

Elizabeth. At age 13, Elizabeth was a budding moviemaker, animator, and webpage designer with a knack for multimedia applications, though she identified herself as a creative- rather than computer-type of person. Elizabeth viewed the computer as a tool that helped her express her creativity. Elizabeth started writing stories in kindergarten with the help of her mother, who would type her dictations so she could then fashion them into books. Bookmaking was followed by moviemaking at age seven, using a handheld analog camera and, with her father's assistance, learning how to use some of its special-effects features. In middle school, she began using software like FrontPage for website design. Because FrontPage did not allow her the technical control she needed to create what she envisioned, she took the two web design classes offered as electives at her school.

Marybeth. At age 13, Marybeth's primary projects involved blogging and maintaining her websites. Marybeth took a particular interest in computing activities that allowed her to socialize. Instant messaging directly connects Marybeth to others in her circle of friends, and blogging extends her social network well beyond her hometown. While in elementary school, she used the computer to play games until her interest in Neopets led her to the Internet. When she entered middle school, she began to use the Internet to participate in social activities. Friends told her about an online blog community and also showed her how to create simple webpages using HTML. Marybeth enrolled in an introductory web design course during the fall semester of her eighth-grade year, and enjoyed it enough to continue with advanced web design. She used her HTML knowledge to update her site once a month and was able to go beyond the templates available to users who do not know how to build using the scripting language. Marybeth also participated in face-to-face computing communities in one of the computer clubs at school. This club opened her eyes to Photoshop, an application she used to support her digital photo-editing hobby and website creation.

Layla. At age 12, Layla's involvement in computing activities revolved around her interest in mathematics, which became quite serious when she joined the competitive mathematics team at her school. Looking for new learning resources, her mother signed her up for an online math community to enable her to take an online course that was offered through the site. Layla began to engage in the community beyond the course, becoming deeply and broadly involved in other areas such as programming, blogging, and discussion boards related to math as well as broader social and political issues. Based on conversations with her online peers, she decided to teach herself C++. Layla used Google to find an online tutorial. After taking the C++ tutorial—which she spent only a few hours on over the course of a couple of weeks—Layla enrolled in the school's programming class as a seventh grader. The programming course prepared Layla to teach herself a code-based 3D graphics application called POV-Ray, which she picked up as a home-based hobby. Her participation in these computing activities strengthened her sense of belonging to the mathematics community and to the virtual community of mathematics enthusiasts in particular.

(continued)

Table 2 Brief case portraits (*continued*)

Stephanie. At age 13, Stephanie was an active music video creator and deeply interested in learning more about programming and exploring the expressive capacity of digital media. At home Stephanie shared a computer with her parents. She attributed the origins of her interest to her friends and their participation in an online community environment where participants are provided with tools to create websites or blogs. She began this informal activity when she was 11. At age 12 she decided to take formal classes based on this growing interest. During her seventh-grade year she managed to take courses in programming, web design, and industrial technology. Stephanie also participated in a contest sponsored by a local science museum during which she and a team created a vehicle that had to accomplish certain tasks. The following year, having exhausted most of the school's technology classes, she "decided to branch out on [her] own." She continued to express a persistent interest in learning more and found several new communities online in which she lurked to pick up knowledge and techniques. She connected her interest in coding and moviemaking to her long engagement in drawing and painting inspired by her grandfather's expertise as a painter.

understand the parents' own experiences with technology, so each interview began with a request for the parents to tell the story of their family and technology. Usually both parents participated, and for some interviews the focal child and siblings also participated. Examples of the questions used in this interview are provided in appendix C. Each Parent Interview was audio-recorded, took place in the child's home, and ranged from 44 minutes to 114 minutes. Seven of the eight interviews were carried out by the first author, frequently with the assistance of another member of the research team. One parent interview was carried out by two graduate assistants.

The multi-informant interview methods used in this study yielded reports on learners' histories in the form of conversations between the interviewers, the learners, and their parents. Responses to questions posed by the interviewers include rich information about children's activities and learning resources, the ways in which children's parents and peers support their learning, as well as children's future goals, attitudes, and interests. The authors view the interview results as stories or accounts and realize that retrospective accounts are subject to biases in memory and that the interview situation itself is a social situation that has its own demands. Despite these limitations, interviews provide unique information not obtainable by other methods.

Coding System

The coding categories for parents' roles in learning were developed based on a collaborative review and discussion of the transcripts from the Learning Ecology and Parent interviews for all eight case-study learners using a grounded theory process (Glaser 1992). Several cycles that included the reading and discussion of transcripts, defining and testing categories, and refining definitions were completed before the coding system was finalized. As a result of this process, seven distinct roles that supported learning were identified and defined: Teacher, Collaborator, Learning Broker, Resource Provider, Nontechnical Consultant, Employer, and Learner. These roles are summarized in table 3 and discussed further in the results section.

Final coding took place in three phases. First, two coauthors independently identified all segments of the 16 interviews that included examples of a parent's involvement in learning. Examples could be reported by either the parent or the child, could be past or current occurrences, and could be sustained activities or one-time events. The unit of analysis was a turn in the conversation. In this first phase, a reliability of 87.2% was achieved. Coding discrepancies were discussed, and a final set of the 16 transcripts was developed with 215 marked segments. During the second phase, the same two coauthors coded 78 of the 215 marked segments as represented in the Parent and Learning Ecology interviews from two of the cases using the coding scheme outlined in table 3. Segments could be coded for multiple parent roles. In this phase, 90.3 percent reliability was achieved. For segments where the coders disagreed, discussions were held to determine a final count and to minimize discrepancies and ambiguity in the coding scheme. Each coauthor then coded three of the remaining six cases. Transcripts were coded using HyperRESEARCH qualitative data analysis software. In the third phase, coding was double-checked. For each role, all coded exemplars were reviewed by one of the coauthors in order to identify possible coding errors. All four coauthors discussed these findings and reached consensus about how to handle errors.

Table 3 Coding categories for parent roles in learning

	Description	Examples
Teacher (T)	Parent has taught child how to do something on the computer over some period of time, which can be either low or high fluency in nature (i.e., word processing to programming). Parent possesses more knowledge about subject than does child.	*Father*: And back then the scanner we had was not very good. So that's when, I think, I started showing [child] Photoshop. So he could draw on Photoshop and include it into his reports. I showed him some basic things and he took off from there. *Child*: Originally when I was learning C he helped me a lot; he does that at work. He got me interested in a few programming languages.
Project Collaborator (PC)	Parent has collaborated with child on a project. Parent may or may not know more about subject than does child. Project is a shared learning experience.	*Mother*: I know that [child] and [father] have a pretty close relationship. He will write macros for him. I know that there has been a lot of collaborative work that is way over my head. They will sit and discuss things. That is a learning process like a workplace.
Learning Broker (LB)	Parent seeks learning opportunities for child by networking, searching the Internet, talking to other parents, and using other sources of information. Signs child up and provides necessary support for endeavor.	*Father*: The only thing he did get help with is there are always the tidbits of educational information you will not get out of the book, and we sat with one of my MIT buddies. It took him and Caleb about eight hours to get the final bug out of this. *Child*: My mom signed up for the Juniper newsletter, and she said they were saying they were short a few members [on the robotics team] and does anyone want to sign up.
Resource Provider (RP)	Parent has provided resources to child beyond the family computer (e.g., books, video equipment, software, online accounts) in support of child's technology learning. Resources can be those owned by parent and used by child or purchased specifically for child.	*Child*: Yeah. I make music too. But I don't have the program right now. My other dad has it, and I asked him to bring it next time. *Child*: I'm not sure, but I think six, seven. I don't know. And then [my dad] got me an HTML book also, so I started learning HTML. I got into websites. *Mother*: Yeah, we got him Macromedia Dreamweaver, that is when he started learning how to do the webpages.
Nontechnical Consultant (NTC)	Parent provides information/advice to child on nontechnical issues such as business or artistic design. Role also covers times when parent provides basic encouragement or advice on topics such as project management and learning organization in order to encourage child to continue his or her learning.	*Father*: I kind of knew that [child] would be like: "Oh, we can do this and this and that." But I wanted him to focus and understand the business side of things. You get a task and you are told to do it this way. I was trying to make him concentrate on the assignment. *Child*: In terms of like charging money for [my IT services], I think that's just 'cause I want to have money for things. My mom also, she has her own, like a business, just so she can do work for people and take deductions and stuff. So I talked to her about it.

(continued)

Table 3 Coding categories for parent roles in learning (*continued*)

	Description	Examples
Employer (EMP)	Parent employs child for technical services rendered. Role can include a formal paid position or more informal activities such as technical support for a home computer.	*Child*: Yeah [in response to question about whether mother has her own computer], but I take care of it and that sort of thing, you know what I mean. All the updating and stuff. *Parent*: No, actually it was because I was working for this new company and I decided it would be good to get [child] to help me. I wanted to bring her something that would be interesting and so just told her, "Heck, why don't you take this piece of software and find really good bugs," and I think that I paid her something like $25.
Learner (LRN)	Parent learns technical skills/content from child.	*Child*: [Father] didn't even know…he doesn't even…like he always asks me to give him like a…how to do that, like you know, like a tutorial on how to do it. *Child*: Well, like I said, I help my dad when he has questions about his work.

Results

Results are presented in two parts. The first section provides a content analysis for each parent role, including the number and range of examples found. Subcategories that help to illustrate how different types of instances are coded as a particular role are also described. The second section provides quantitative summaries of the range and density of parent roles for each child.

Part 1. Content Analysis of Parent Role Categories

Parents as Teachers

> "I try to give him some idea. If he has some big object, I tell him that maybe he can split it up into smaller objects. Just introducing the idea of objects. I'm talking to him a little bit about that. But I don't want to get too technical. It'll get boring."
>
> *Alex's father*

> "Dad said he would show me how to videotape. He showed me some special effects…. Like basically the ones that come with the camera. Like making you really skinny or fat or negative, things like that."
>
> *Elizabeth*

> "I think she picked that [HTML] up mostly on her own. I explained to her what the concept is though and how you need to define it so that…it can be shown anywhere."
>
> *Marybeth's father*

All eight case-study learners and their parents gave accounts of at least one parent who played the role of Teacher. As a Teacher, the parent has more expertise than the child and uses this knowledge to offer guidance about a technological subject matter. For example, Alex's father talked about how he had gently introduced the programming concept of decomposing visual objects into smaller ones in a Flash animation. Another parent had helped to explain concepts as a child learned to program in the C programming language while taking an online course. A third parent reported a onetime explanation he had given his daughter in response to her query about how the Internet works.

Four subcategories were identified to represent the types of technical content that parents were teaching: *multimedia, programming, engineering,* and *basic computing skills*. Multimedia included any sort of digital media, including putting images and text together in PowerPoint, working with the professional photo-editing program Photoshop, making music with digital studio software, and discussing web design considerations. Programming included any sort of formal programming language (such as C or Java), any sort of scripting language (such as JavaScript), and/or any markup language (such as HTML). Engineering included electronic or technical projects such as robotics and constructing digital models using computer-aided design (CAD) software. Basic computing skills included basic applications such as word processing or introducing a child to touch-typing.

One of the male case-study learners had received parental instruction across all four topic areas, while another received instruction only in programming. The other six case-study learners gave accounts of instruction in two or three topic areas. Three boys and two girls had received instruction in multimedia. All of the boys and two of the girls had received instruction in programming. It is noteworthy that the two girls who did not report receiving parental instruction in programming were enrolled in a school programming course at the time of the interviews, and both had at least one parent who was a programmer. One boy and two girls reported that they had received instruction in engineering, with the boy having received seven unique instances of engineering instruction and the girls each having received one. Six of the eight children (three boys and three girls) had received some help with basic skills.

For many of the children, the instances of being taught by a parent usually had occurred in the past. Several of the children in the sample articulated that a shift had occurred as they got older, and for some, at the time of the interview it was more common that they taught their parents.

Parents as Project Collaborators

> "He did a whole series of little animations. Later he put music on. They were very short. It takes all of these frames. I helped to make the little characters."
>
> *Jonathan's mother*

> "We went through those kits. We did the Hyper Peppy thing. We did a whole bunch of that kind of stuff. And then eventually some of the robotics stuff."
>
> *Caleb's father*

Some parents in the sample played an important role by collaborating with their children on technology-related projects. The role of Project Collaborator is distinguished from the role of Teacher because rather than provide explanations or demonstrations when a child requests help doing or understanding something technical, parents work with the child on a project in which both are engaged. Five of the eight case-study learners had collaborated with a parent. Although collaboration was coded less frequently than some of the other roles, parents and children who collaborated had worked on a wide variety of projects, including creating a Claymation video, editing a soundtrack for a figure skating performance, putting together electronics kits, setting up a home computer network, and building robots. In some of the examples, a clear division of labor was described. One case-study learner reported that when she was five years old and did not yet know how to type, she used to dictate her stories to her mother, who typed them for her. In other examples, the parent helped by providing just-in-time conceptual knowledge. One father reported that he had worked with his son on the mechanics of a robot's arm so that it could move up and down and pick up a ball, but that his son had done all the programming. In some instances the parent's role in the collaboration was nontechnical in nature. One of the mothers reported having brought her artistic background to a Claymation collaboration by helping her son make the figures while he took care of the technical aspects of the project.

Female case-study learners and their parents gave fewer accounts of project collaboration. Two of the four girls had collaborated once with a parent. Both instances of collaboration had occurred several years before the girls' interviews. One of the girls had worked with her father on problems she received as part of an online problem-solving course she took in third grade. The other case involved the mother who had helped her daughter type stories. Among the male case-study learners, the frequency and type of collaboration initially tended to be more ongoing, though as with the girls it had changed with age. Three of the four boys had collaborated with a parent, and together they spoke of 12 unique collaborative instances. One of the boys had six while the other two had three each. The boys had often collaborated with their parents when they were young, but as they gained expertise, they tended to work alone or collaborate with peers on school projects.

Parents as Learning Brokers

> "I know the kind of stuff he does like, so I would try to get him signed up for that stuff, like the—the programming classes—those were really hard to get into."
>
> *Craig's mother*

> "I talked to the people at my job, and they were open to looking at his portfolio."
>
> *Alex's father*

> "My mom signed me up [for an online math learning community]. Afterwards I stayed on willingly because I found it so interesting."
>
> *Layla*

Parents identified as Learning Brokers had played key roles in enabling their child to access learning experiences. Parents of seven of the children in the sample (four boys and three girls) had played the role of Learning Broker. By identifying technological fluency-building opportunities, parents may contribute to their child's technical learning even if they themselves do not possess expertise in the field.

After identifying all instances of brokering, three subcategories were identified within this more general activity: providing access to *people and places*, providing access to *formal instruction*, and providing *transportation*. Several parents in the sample mentioned that they had referred their children to friends and connections in the technology industry, sometimes for the purposes of seeking answers to a specific technical question and occasionally for other reasons such as securing a summer job. Some parents also had provided access to places such as a technical workplace or a computer store where the child was exposed to the most recent technological developments. Several parents had searched for, found, and signed their children up for formally organized learning experiences such as camps, clubs, and classes. Transporting a child to an activity, while not dependent on the parent's knowledge or connections, was also identified as an important aspect of enabling a child to access learning opportunities.

Although each of the four boys had at least one parent who had connected him to people and places, including high-tech workplaces and friends who create software and hardware, only one of the girls had experienced this type of brokering. Her father regularly took her to a technology store to discuss the new technologies, and he had once taken her to his workplace. One girl and one boy each had a parent who reported providing transportation. The mother of the boy woke up early on Sunday mornings to drive him to the early church service where he shadowed and interned with the man responsible for the weekly video documentation of services. Two boys and two girls had parents who had found and signed them up for formal learning opportunities. One mother had read about the robotics club at her son's school and had signed him up, thinking it was something he would enjoy because of his interests in engineering. Another mother, believing that her daughter would benefit from classes for gifted youth that her school system did not offer, had searched online and found a web-based programming class in which she had enrolled her daughter.

Parents as Resource Providers

> "I found one of my UNIX books—I had an old book that I gave him and he has been using that—he used the terminal and that actually helped."
>
> *Craig's father*

> "We just recently got a digital camera. My family has gotten the camera and I've probably used it more than they have."
>
> *Elizabeth*

Because minors typically do not have the financial means to purchase hardware or software, parents are important gatekeepers in their children's access to the tools required to spark an interest in technology-based activities. Parents can provide resources for their children in two ways: *lending resources* and *purchasing resources*.

Parents lend resources by allowing their children to use the computers, software, digital cameras, video equipment, high-speed Internet accounts, books, and other resources that they already own.

Seven of the eight children in the sample, including all four of the boys and three of the girls, had lenders as parents. All four boys had also been encouraged to take advantage of the professional-grade products and resources used by their fathers in their technical jobs, such as books about the C++ programming language or specialized programs such as SolidWorks, a CAD software package. Only one of the girls reported having borrowed a parent's professional resource, her mother's JAVA book. The three girls also reported using productivity software available on the family machine, such as the Microsoft Office suite of tools (Word, Excel, PowerPoint) and Windows Media Works.

Parents also reported having purchased new learning resources specifically for their children's use. All four of the boys had their own computer, while three of the four girls shared a family computer. Because the four boys had had their own computers "for years" and "as long as I can remember," accounts of hardware purchases were less common than purchases of courses, software, robotics kits, and books. Four of the five children whose parents had purchased resources for them were boys. This reflects the pattern seen in the lending category, where the parents of boys reported being more active than the parents of girls in providing material resources to support their child's technology activities. Parental provision of resources started at a much earlier age for the boys than for the girls, with fathers having purchased things like robotics kits to work on with their primary school–age sons. As their sons got older, these purchases had progressed to professional-grade software such as Macromedia Flash and Dreamweaver.

Parents as Nontechnical Consultants

> "Part of the process was him learning that not everything is worth his time. No, I don't provide that filtering, otherwise he'll never learn to do it. 'Is that a good use of your time, son? Just because you can fix it, does it mean you should?' And that's what I ask him now."
>
> *Caleb's father*

> "My dad was encouraging me to learn about programming, which I am not really interested in, but he said it would be a useful skill to know."
>
> *Marybeth*

> "He is quite an accomplished figure skater, and he has music that he has to have for his programs, so he has been involved editing the music. That is something that I help him with. I do not really know much about technology at all, but have more music background."
>
> *Jonathan's mother*

Parents can provide nontechnical information or advice to their child to foster a technical learning experience such as a project or a class. Seven children in the sample (four boys and three girls) had a parent who had offered them nontechnical support. Three subcategories of nontechnical support offered to children by their parents were identified in the sample: *encouragement, problem-solving guidance,* and *field consulting*.

In some instances parents had encouraged their child to learn something new, such as when one girl in the sample had been encouraged to learn a programming language because her father thought it was a good idea for the future even though the child had not initially been interested. The encouragement subcategory also includes instances in which a parent recognized the challenges his or her child was facing—whether that be the frustration of learning a new programming language as part of an online class or staying on a robotics team when the interpersonal relationships between team members had become strained and the collaboration unsuccessful—and offered general encouragement to continue with a potentially important learning experience. The three girls whose accounts offered evidence of nontechnical support had all received encouragement, as had two of the four boys.

Parents offer problem-solving guidance when they help their child work through a complex technological learning situation. This includes general approaches to learning, such as focusing on one thing at a time, and more specific instances of guidance such as buying a notebook to record project ideas, map out resources needed, and plan possible timelines for work production. In the sample, all of the boys and none of the girls reported having received this type of support from their parents.

Parents act as field consultants when they offer expertise or knowledge from another field that contributes to a particular technical learning pursuit in which the child is involved. One girl and two boys from the sample had received support of this type. One mother, who had an artistic design background, had offered advice about color combinations to her son who was putting together a website, and a father had helped his son develop a pricing model for his online business based on his general knowledge of finance. Another mother had offered her skills as an editor to her daughter as her daughter worked on digital storytelling pieces.

Parents as Employers

> "I'm like the administrator of our mail and email and all that stuff. It's all posted on my server."
>
> *Jonathan*

> "I wanted to bring her something that would be interesting and so just told her, 'Heck, why don't you take this piece of software and find really good bugs,' and I think that I paid her something like $25."
>
> *Marybeth's father*

> "She [Stephanie's mother] knows a lot about technology, but she doesn't use it in her everyday life as much as I would like. She will shop online, but I'm the one she looks to, to download things online."
>
> *Stephanie*

Parents in the sample often entrusted their technologically skilled children to perform technical services for them. All four boys and two of the girls had parents who had played this role. These acts of employment were subcategorized as *unpaid projects, paid projects,* and *technical support*.

Two children in the sample, both boys, had been asked by their parents to complete tasks of limited duration without pay. One had been asked to build a website for the family, and the other had created a digital slideshow of the family's vacation photos. Only one child in the sample, Marybeth, had been paid for her services spending a few hours discovering bugs in the software program her father was developing at work. Three children in the sample were counted on by their parents to maintain household or parental computer equipment on an ongoing basis. Two boys had offered to help their less technically inclined mothers maintain and troubleshoot problems with their computers. One of these boys reported having updated the software on his mother's machine, and the other would come to his mother's rescue whenever her computer crashed or the printer stopped working. The one girl who had offered technical support to her parents provided assistance of a different nature. Because her mother worked in the technology industry and knew quite a bit about software and hardware, the girl helped her download files from the Internet and assisted with other online consumer tasks.

Parents as Learners

> "Sometimes my mom gets curious about what I know about HTML and she will ask how to do that and I will explain to her how it is done."
>
> *Marybeth*

> "I pretty much teach my mom what she knows. I've taught her how to use some of iMovie. I also like to manipulate photographs. I've taught her how to do that."
>
> *Elizabeth*

Teaching another person has the potential to be a valuable learning experience. Six of the children in the sample, three boys and three girls, had taught their parents something about computers and technology. The range of content taught by these children included programming, Flash, word processing, the basics of the Mac interface, iMovie, digital photo manipulation, HTML, and PowerPoint.

Some children had provided assistance with relatively general topics such as word processing or PowerPoint. Several of the children from the sample had shared knowledge drawn from their particular area of expertise with a parent who was not knowledgeable in the area. For example, one boy, whose specialty is animated movies, had helped his father with Flash. A girl who specializes in making videos had helped her mother with iMovie. Another girl had built her own website and used the knowledge she gained while working on the site to help her mother understand HTML.

Two of the adolescents had surpassed their parents' expertise and at the time of the interview were teaching their parents in areas where those parents had considerable knowledge and industry experience. A father who is a programmer and engineer had helped his son learn how to program when he was in elementary school, but at the end of middle school the roles had reversed and the boy reported having helped his father with programming issues that came up at work.

Part 2. Quantitative Overview

For each child in the study the total number of roles played by any parent (range of roles) and the total number of roles played by all parents (density of roles) were calculated. For density of roles we combined the total number of roles played by the father (and/or stepfather or male guardian) and the total number played by the mother (and/or stepmother or female guardian).

Range of Parent Roles

Figure 1 shows the range of learning roles for each of the case-study learners, with a possible total of seven. For example, Jonathan, Craig, and Marybeth were coded as having all seven roles represented, but Layla had only three. The range of roles is only somewhat informative, because it does not say anything about frequency or intensity. The large range in the number of unique examples of each parent role coded for each child hints at substantial variation in the continuity or intensity of parent support for learning. At the upper end, Craig's Learning Ecology and Parent interviews yielded 52 unique instances of roles. Eighteen of these were examples of the Resource Provider role. Craig's parents had bought him several types of professional software, books, a laptop, and summer camp experiences. His father had lent him professional books on programming languages. His mother had played the Learning Broker role several times when she found specific extracurricular activities. On the lower end, Layla's interviews yielded only five unique instances and three roles. Her mother had played an important role in connecting her to an online community of peers and adults interested in computational topics. The interaction with online peers had led Layla to seek out digital resources to learn about programming and to sign up for a course at school. Despite her father's profession as a programmer, he was not involved in her learning about programming. The ranges of examples were nonoverlapping for the male and female case-study learners. For the females, 5 to 11 unique examples were obtained, with a mean of 8.5. For the males, the range was 14 to 52, with a mean of 26.5. The age at which these learners had been recognized as interested in computing activities (by themselves or their parents) also differed. In general the girls' interest was reported to have emerged much later than the boys' interest. The relatively shorter duration of time for the girls' families between the onset of fluency-building activity (which happened on average later than for the boys in our case studies) and the point at which these families were interviewed may account for the differences in the mean number of examples of learning support offered. Regardless of cause, the pattern is important to follow up on.

Density of Parent Roles

Figure 2 shows the total number, or *density*, of parent roles played per child, with a maximum possible total of 14 (calculated by summing the number of roles played by all of the child's parents; e.g., if both mother and father played all seven roles, the parent role density would be 14). As both of these graphs suggest, in

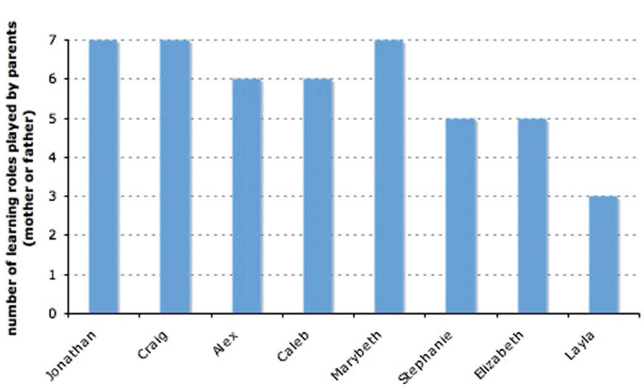

Figure 1 Range of learning roles: Number of learning roles played by either parent for each case-study learner.

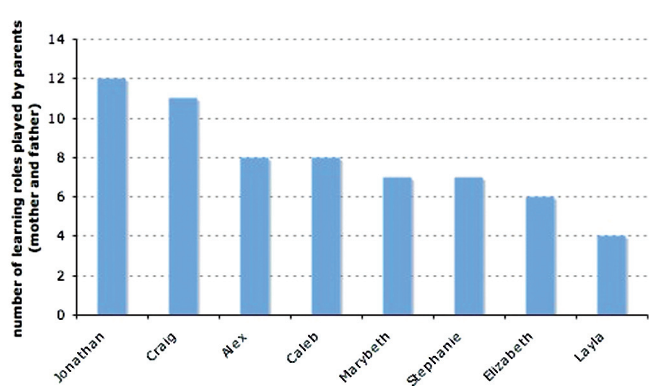

Figure 2 Total number of learning roles: Number of learning roles played by mother plus those played by father for each case-study learner.

this study's selective sample of highly engaged adolescents raised by parents with high levels of technical expertise, individuals differed in the range and density of supportive roles played by their parents. On the upper end of the distribution Craig and Jonathan have densities of 11 and 12 roles. In Craig's case, his mother had played all roles except Teacher and Collaborator, and his father had played every role except Employer. On the lower end Layla and Elizabeth have densities of four and six roles. The distributions of this metric for boys and girls are nonoverlapping. The range for the boys was 8 to 12, and for the girls it was 4 to 7.

Discussion

When addressing issues of equity involving participation in new media activities, one must go beyond a focus on access to tools to begin to more deeply theorize the nature of supportive learning resources (Warschauer 2000; Barron 2004; Hargittai and Hinnant 2008). This study focused on children's learning with and from parents, a frequently important aspect of a child's learning ecology. By using qualitative methods to obtain rich first-person accounts from highly engaged adolescents and their parents, this study extends prior work on how parents support computing activity. One prior survey study established that parent coactivity predicted child activity with computers (Simpkins, Davis-Kean, and Eccles 2005). The research presented here suggests that the general category of coactivity has many forms that are usefully distinguished. Seven parent roles that were instrumental for children's learning and project work were reliably distinguished: teaching, collaborating on projects with, providing nontechnical support to, brokering learning opportunities for, providing learning resources for, learning from, and employing children to assist with technical projects. Each role was instrumental for learning, although form and function varied. Although the Teacher and Collaborator roles provided the most direct opportunity for parents to scaffold their child's knowledge and engagement through face-to-face interactions, the Learning Broker role was equally powerful when it connected a child with people or experiences that could support learning. The Nontechnical Consultant role supported engagement and offered assistance that furthered a child's project, and the Resource Provider role procured the physical tools of production or resources from which a child could learn. The Employer and Learner roles gave the adolescents a chance to be more expert and put their knowledge into practice.

These roles can be viewed with a broader eye to what they offer the child beyond content knowledge. For example, parents' values and implicit hopes for their child play out in these roles (Lareau 2003). The Learning Broker role provided several examples of powerful socialization experiences where parents connected their child with a person, place, or experience. One parent described how he had helped his 13-year-old son develop a social network of professionals (see Ackerman, Wulf, and Pipek 2002) that could help him in his future career-related activities. For more than one child, visits to a large electronics store provided opportunities to review emerging technological innovations. Similarly, by formally employing a child with a financial agreement or by giving the child a less formal responsibility for technical support for the family, parents provided opportunities for lessons in responsibility while communicating to their child their belief that they could make valuable contributions based on their developing knowledge. When playing the role of Nontechnical Consultant, parents used their child's interests in specific activities as opportunities to support the development of their ability to plan, justify, and follow through on projects of their own choosing. In some cases, the extensive financial support offered in the Resource Provider role was linked to the ability of the child to convince the parent that they had a well-conceived plan. In these cases parents provided a context for their child to practice planning, documentation, and argumentation skills.

Finally, some of the cases provided examples of an explicit socialization of attitudes toward entrepreneurship, technological innovation, and sharing of workplace-based knowledge. For example, when one of the male case-study learners was about to drop out of his robotics team because he felt that his teammates had intentionally prevented his contributions and had personally insulted him by hiding their code, his father provided him with alternative theories based on his own workplace experience with coworkers. His mother meanwhile prompted him to think about how prepared he would be for the competition next year. These alternative explanations simultaneously protected his ego and encouraged his persistence. In another example, a male case-study learner and his father reported extensive conversations about the technology industry. In these conversations many perspectives had been shared, and the discussions had included consideration of the ethics of practices employed by computing companies to ensure continuing profit, or what one of the case-study children referred to as the "planned obsolescence" of software or hardware.

Although all of the case-study learners demonstrated high levels of engagement at the time of the interviews, the brief learner profiles (see table 2) point to the importance of attending to the dynamics of learning across developmental time and life setting (Bronfenbrenner 1979; Lemke 2000). For many of the learners in the present study, activities that began with help from parents or peers evolved and were sustained with greater independence. Using Hidi and Renninger's (2006) model of interest development and associated criteria, each of these adolescents in the study can be classified as expressing at the time of their interview an *individual interest*, defined as "a relatively enduring pre-disposition to re-engage particular contents over time" (p. 111). This phase of well-developed interest is marked by positive affect, a willingness to persist through challenges, and the active seeking out of new learning resources. Although all of the participants were interested and committed learners (diSessa 2001), age differences in the *onset* of engagement in fluency-building activities were observed that resulted in substantial differences in opportunities to learn during the years before middle school.

The early emergence of activities that involved programming and engineering for some of the case-study participants was striking and had implications for expertise development. Playful activities, typically instigated by a father, paved the way for engagement in more formal learning opportunities such as classes, clubs, or camps and led to the provision of resources such as books, software, and computing tools. Differences in the ages at which children became engaged were coupled with differences in the enactment of possible parent roles more generally. Analysis of the interviews indicated differences in the form and intensity of parent involvement even within this small group of case-study learners, all of whom had relatively high levels of access to computing tools and parents with domain expertise. Substantial variation was found in the range of roles played by either parent and the total number of learning roles played by both parents. At the extreme support end of the continuum were cases where parent involvement was arguably critical in the onset of activity, the nurturing of content knowledge over years, and the persistent engagement of their child. In these cases, at least one parent had high levels of domain expertise and shared some of this knowledge with his or her child during collaborative projects or within assignments given by schools or online courses. At the other end of the continuum were parents who offered minimal functional support for learning, as reflected by the seven role descriptions, despite the parent's content knowledge and the presence of child interest as indicated by his or her independent pursuit of learning opportunities. Fewer roles were found for those learners whose interest emerged during the middle school years. Possibly, latent interests were present that might have been engaged earlier had the conditions been right.

High interest has payoffs for learning in the form of increased attention, promotion of self-regulation, generation of curiosity questions, diversity of learning strategies, and goal setting (for a review, see Hidi and Renninger 2006). Although parent roles were critical resources in the present study, learning was also distributed across settings. Learners took advantage of school-offered electives, joined clubs, attended camps, found online tutorials and examples, participated in affinity groups, read books and magazines, and engaged nonparent mentors in learning partnerships. Interest-driven learning led learners to create and sustain opportunities to further their own development. Further, the case-study portraits provide qualitative evidence that interest-driven learning can have secondary developmental outcomes—such as being given new roles in the community—and that these roles can drive new learning goals, opportunities, and perceptions of one's own capacity to contribute to the activities of others. These secondary outcomes and related social processes have been less theorized but can be key to learning (Barron 2006). Participants in the present study described invitations to apprentice with more-expert others, intern in companies, and serve in a teaching or helping role. Given the driving nature of interests for engagement in learning activity and its high payoffs for knowledge development, understanding how to nurture interest in the earliest stages is critical—as is understanding how possible interests are recognized by others.

Future Directions and Limitations

The sample studied was small and selective. The community from which all eight subjects were drawn is known for its role in the broader technology industry. In addition, analysis was based on parent and child reports of learning rather than on direct observation. These factors limit the generalizability of the results and suggest the need for additional research that uses observations as well as interviews. Three important directions for future research can be described.

Gender and Interest Development

First, a further exploration of gender and interest development as they relate to parent roles is in order. The boys in the present study were more involved with their parents in technology-based hobbies than were the girls. However, because of small sample size, strong claims cannot be made about gendered patterns in parent-child technological activity, particularly because of the presence of gender confounds. For example, although all of the case-study learners had at least one parent with content expertise, and more girls in the sample had both parents in the computing industry, other differences were observed among the families. In contrast to all of the girls in the sample, three of the boys had mothers who worked only part time or not at all, which might have allowed those mothers to pay more attention to nurturing their sons' interests. In addition, the methods used in the present study relied on parent and child reports and coding was based on these reports. However, the persistence of the "shrinking pipeline" phenomenon (Camp 1997), wherein fewer women are seen the higher up the academic ladder one observes, suggests the importance of pursuing the broad array of factors that might contribute to differential participation in activities that might build interest, knowledge, and confidence.

For example, careful documentation of the emergence of interest and informal teaching roles would be productive. Beyond extending the present study's methods to include tools that will allow for larger sample sizes, observational studies of parent/child interactions in home or laboratory settings would be of value. Theories of interest development have made progress on describing phases of interest that mark different levels of commitment to a domain, topic, or skill (Hidi and Renninger 2006). Less is known about the early emergence of interest and what variables influence it. One study that focused on the early emergence of interest during the preschool years found that boys in the sample were six times as likely to develop a conceptual interest than were girls (Johnson et al. 2004). Because this study was primarily based on self-report, it cannot tell much about how these stable interests emerged or the degree of support they were given by parents, peers, or siblings. However, the striking difference in parents' reports of the rate of conceptual interests for boys and girls deserves to be followed up in detail, particularly in light of other studies that show gender differences in the probability of engaging in scientific conversations with parents. Crowley et al. (2001) found that boys touring a museum exhibit with their parents received three times as many explanations as girls. Gender differences were also found in a longitudinal study of the relationship between science talk between mothers and their children at age 9 and children's reading comprehension of science texts at age 11: Mothers were more likely to talk science with their sons. Further, the amount of science talk at age 9 predicted reading comprehension at age 11 (Tenenbaum et al. 2005). Together, these studies suggest that parent-child interaction before school begins is an important site for investigating the origins of individual differences in knowledge and interest.

Naturalistic studies would allow for the documentation of normally occurring play activities at home. However, children and their parents live in broader cultural contexts that help shape perceptions about what it means to be a girl or boy and what activities fit with broader stereotyped notions of appropriate activities. The toy industry markets to boys and girls differently, and research suggests that parents and children hold gender-typed toy preferences (Langlois and Downs 1980). Experimental studies that offer parents and children a set of gender-typed toys might help reveal the roles that gender, expertise, and interest play in the genesis of parent-child activity.

Parent Roles in Other Environments

Second, the analysis of the informal teaching and collaboration roles identified in the present study can be extended to peers, teachers, and other adult mentors. The reader may be wondering how what was learned about these Silicon Valley children, whose parents are employed in technical professions, could be extended to less technically involved learning partners. Many of the key roles did not require that parents have more extensive knowledge in or experience with computing and technology. We believe that these roles may be observed in other learning contexts. In our current studies, we are investigating the validity of this generalization in an analysis of how community and afterschool environments support learning to create with new technologies. As researchers move toward more-refined assessments of the generativity of any learning environment, frameworks for characterizing the quality and quantity of teaching/learning relationships will be critical. Identifying strategies for documenting the existence and distribution of these kinds of roles might lead to useful measurement tools. More generally, characterizing roles in detail may be practically useful for parents and others who support children's development, because discussion of possible roles may help them imagine new possibilities for supporting children's learning in the future. In the present study, the roles of Learning Broker, Collaborator, Nontechnical Consultant, Employer, and Resource Provider were key sources of encouragement for many of the case-study learners, and these roles did not require specific content knowledge. Documenting the enactment of these roles in a broad range of environments may be helpful for generating strategies for bridging divides in access to learning opportunities. This kind of work is critical. Recent policy documents reflect the concern that children who do not have adult role models to guide this learning will fail to develop the technical skills, knowledge, and dispositions necessary to succeed in the 21st century (Gee 2008).

Parent Roles More Generally

Third, more can be learned about the forms, functions, and origins of parent roles in learning more generally. The majority of the findings on parent roles in learning arise from a body of research that investigates links between parent involvement in school and student achievement. In that work, parent roles are typically investigated through surveys that query the frequency with which parents engage in specific behaviors that are plausibly related to learning outcomes. Typical categories include physically visiting a child's school, discussing educational topics, helping with or monitoring homework, and encouraging or rewarding hard work, as well as literacy-related activity management and expectations for educational attainment (Lee and Bowen 2006). These studies emphasize the agency of the parents in directing activities that are school related. A more nuanced look at roles, including roles that nurture interest in academic and nonacademic topics, might be productive. An expansion of the analyses to look at how and why parents engage in particular ways and how engagement relates to their experiences is needed (for a useful framework, see Barton et al. 2004). The importance of understanding the transactional nature of human development and the role of the child in self-socialization (Corsaro 1997, 2004) suggests the related importance of using research methods that can reveal the role of the child in mediating, inviting, and shaping parents' involvement in their child's learning environments.

Conclusion

How new tools of learning and production are taken up and shared is important to understand. Despite the level of privilege the eight case-study learners in the present study enjoyed, the analysis of parent roles offers important insights for those interested in the intentional design of learning environments that can bridge divides and promote equity in empowered uses of computing. Family-based informal learning and teaching processes such as the ones described in this paper are important mechanisms of intergenerational learning. Family learning is not the only or even the most powerful learning pathway, however. Children and adolescents will develop higher levels of engagement in creative fluency-building activities when they have opportunities to explore computational possibilities through projects, encounter models, access resources such as books or tutorials, and have conversations with more-expert partners. No fundamental reason restricts these learning and informal teaching roles to parents. Understanding the generativity of a variety of learning-partner roles might help mentors and teachers imagine new ways to support the learning and development of children, even if they themselves are not experts in a domain. In addition, though parent roles were an important influence for the case-study learners in the present study, learning and supports for interest development were distributed across settings and resources, including books, classes, peers, and assets in the community. Regardless of how it begins, learning driven by interest is particularly likely to lead to self-defined opportunities that cross boundaries of home, school, and community and become progressively self-sustained (Barron 2006). An ecological-systems view of learning points to the value of seeding and encouraging interest development across the multiple life spaces in which children spend time and to the value of enriching opportunities for such interests to be noticed, nurtured, shared, and taken up.

Appendix A: Fluency-Building Items from Interest, Access, and Experience Survey

How often have you done the following computer-related activities? *(please mark only* one *box per item)*	Never	Once or twice	3 to 6 times	More than 6 times
Created multimedia presentations that included pictures or movies or sounds using PowerPoint or another application	☐	☐	☐	☐
Written code using a programming language like C, Java, Logo, Perl	☐	☐	☐	☐
Made a publication such as a brochure or newspaper using a desktop publishing program like PageMaker or Word	☐	☐	☐	☐
Started your own newsgroup or discussion group on the Internet	☐	☐	☐	☐
Created a website using an application like Dreamweaver or FrontPage	☐	☐	☐	☐
Hand-coded a webpage using HTML	☐	☐	☐	☐
Published a site on the Web so that other people could see it	☐	☐	☐	☐
Created a piece of art using an authoring tool like Photoshop or Paint Shop	☐	☐	☐	☐
Designed a 2D or 3D model or drawing using a tool like CAD or ModelShop	☐	☐	☐	☐
Built a robot or created an invention of any kind using technology	☐	☐	☐	☐
Used a simulation to model a real life situation or set of data (*e.g., population over time, the spread of disease, or speeds with varying resistance*)	☐	☐	☐	☐
Made a database	☐	☐	☐	☐
Created a digital movie	☐	☐	☐	☐
Created an animation or cartoon	☐	☐	☐	☐
Created a computer game using software like Game Maker or through a programming language	☐	☐	☐	☐
Created a piece of music	☐	☐	☐	☐

Appendix B: Sample Learning Ecology Interview Questions

1. So let's start by talking about the story of you and computers. Can you tell me about the first time you remember using a computer? Where were you? What did you do? Who was there?
2. What happened next? Prompt across preschool, elementary, middle school years for:
   a. What did you do at home? Who were you working with? How did you learn to do that? Were you playing any games? If so, what type? What would you do on the Internet?
   b. Let's talk a little bit about school. What sorts of things were you doing at school? How have you learned to do that? Who are you working with? Have you taken any computer or technology classes? Participated in technology-related clubs? How did you decide what classes/clubs to participate in?
   c. What about other places like a friend's house? A church? A community center computer club?
3. Are you teaching anyone what you know about computers?
4. If you could learn anything about computers or how to use them, what would you learn?
5. Do you have plans for learning more?

Appendix C: Sample Parent Interview Questions

1. Can you tell me the story of your family and computers…
   a. Is there a computer at your house? When did you get it? Who uses it?
   b. Who would you say is the computer expert in your house?
   c. Who teaches whom?
2. What are your own experiences with computers?
3. Can you tell me about the first time you remember FOCAL CASE NAME using a computer? What did he/she do? Where was it? Who was involved? Did he or she ask you questions along the way?
4. Can you talk a little bit about FOCAL CASE NAME's development and interest over time?
5. How would you describe your involvement?
6. Does FOCAL CASE NAME ever talk about their technology project work? What kind of stories have you heard?
7. Have you ever seen their project work? What did they show you? What did you think?
8. I imagine that FOCAL CASE NAME is becoming so computer savvy that they might ask you to buy tools for them. Have they? What kinds of things have they asked you for?
9. Did you ever give or suggest any relevant equipment or learning resources (books, magazines, websites) to FOCAL CASE NAME?
10. Have you tried to find opportunities for them around their interest in computers and technology?
11. Do you have rules about FOCAL CASE NAME's computer use?

Acknowledgments

This research was supported by grants from the National Science Foundation (REC-238524, REC-354453) awarded to the first author and to the LIFE center (http://life-slc.org/). Any opinions, findings, and conclusions expressed are those of the authors and do not necessarily reflect the views of the sponsoring agencies. We are grateful for the participation of the families involved.

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