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Towards a model of technology and literacy development: Story listening systems☆

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Abstract

This article lays out a program of research designed to address one specific need of young children—to learn how to write—based on one specific ability of young children—the ability to tell stories. The model underlying this research program describes how non-screen-and-keyboard-based technologies that *listen* to children can be used to support their emergent literacy behaviors and have an effect on their subsequent writing skills. Four components comprise the model: the importance of *emergent literacy behaviors*, which are features of literate language that are demonstrated in children's oral language; the critical role played by a *socially situated peer*; the design of *non-keyboard-based computational technologies*; and the potential of information technologies that encourage *construction* rather than *consumption*. This article presents information about one kind of technology that fits the model—the *story listening system* (*SLS*)—and describes a number of implemented SLS and an evaluation of their use by children.

Keywords: Literacy; Writing skills; Story telling; Story listening systems; Discourse; Language development

"*Narrative ability is the single most important language ability for success in school*" (Feagans & Appelbaum, 1986, p. 359)

1. Introduction

Multiple, and technological, literacies have become the topic of considerable research. However, reading and writing literacy remain the basis of education, and the prerequisites to science, mathematics,

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and technology fluency. Effective writing skills are important in all stages of life, from early education to future employment, yet many children in the United States lack even basic writing skills. In its *1998 Condition of Education*, the United States Department of Education's National Assessment of Educational Progress found that only 31% of 11th graders (17-year-olds) were generally able to write complete, sufficient responses to questions, while only 2% were capable of providing effective, coherent responses (Snyder & Wirt, 1998). Reading and writing skills are not learned only in school, however. Children prepare themselves for later literacy in many important ways long before first grade (Heath, 1983). And preparation for writing literacy consists of more than knowing how to form letters with a pencil. It includes (1) treating language as an object, i.e., metalinguistic awareness (Cazden, 1976); (2) maintaining cohesion and reference in oral language (to introduce a new character by saying "The man wearing blue" as opposed to "he"...but to refer back later by saying "he"); and (3) making one's communicative intentions known (e.g., "I'm going to tell you about my day").

Many of these *emergent literacy* (Teale & Sulzby, 1986) skills are acquired first in language play and in storytelling. Many of them are acquired in the context of children's interactions with peers, in early play contexts. Peers push one another to make communicative intentions known clearly (Goncu, 1993) and play a critical role in the acquisition of storytelling skills. For example, Preece (1992) found that children's interactions with each other contributed to the modification, expansion, increased coherence, and complexity of their anecdotes and stories. Preece's study revealed that children are active, alert, engaged, and even aggressive listeners. Educators have begun to recognize the importance of the peer context, and address it through classroom activities such as sharing time (Gee, 1986; Michaels, 1986), round-robin storytelling, and the editor's corner.

Technology, and particularly tangible non-screen-and-keyboard-based technology, can play a unique role in supporting emergent writing literacy activities. In the remainder of this article, a model of technology for literacy is proposed, whereby four essential traits allow technology to effectively scaffold literacy. Those four traits are embodied in a suite of technologies, called Story Listening Systems (SLS). The four traits are (a) children's oral storytelling skills as a bootstrap to literacy, (b) peers as playmates *in* the SLS or *with* the system, (c) the kind of embodied play away from the desktop that is most comfortable for young children, and (d) children's constructions of their own personally meaningful content, in contrast to consumption of content devised by others. The effectiveness of these systems is evaluated using three crucial predictors of literacy: (i) decontextualized language (ii) collaboration with peers, and (iii) metalinguistic awareness. Theoretical and empirical work that provides a framework for fostering development in each of these three areas is briefly reviewed in the next section to provide the background for the research program that is the focus of the present paper.

2. Background: Essentials for literacy

Wells (1981) describes three broad phases of language development. The first involves the discovery that language is a pattern of sounds that takes on meaning and purpose. In the second phase children come to understand the social aspects of language, that assumptions and values are encoded in particular linguistic representations and that these values are specific to a particular community (e.g., the style of language used on the playground is different from the style of language used at school). These first two phases involve a close link between speaking and doing. The third stage of development involves the creation and manipulation of language designed for an audience that is spatially or temporally separated from the author. Wells calls this stage "literacy," and defines it as the ability to communicate with an audience not in the immediate physical or temporal context.

2.1. Decontextualized language: Language that can be understood outside of its original context

Literacy, then, is the ability to make meaning for others across space and time. Only in this stage does language have permanence. It can be used for reflection, memory, and sharing meaning with others not currently present. Children's use of literate language occurs, in a sense, the first time *meaning* is separated from *context*. It is in this way that language becomes "decontextualized," or removed from its original context, and reworked for a new audience. Literacy as "decontextualized" language use is a central aspect of the literacy definition used in the current work.

The distinction between "inside–out" and "outside–in" literacy skills is another way literacy has been described and defined (Whitehurst & Lonigan, 1998). The actual act of writing is based on "inside–out literacy skills" such as phonological awareness, knowledge of how to form letters, and the kinds of punctuation involved in writing. Outside–in skills relate to the function and features of writing in the world, and it is those skills that will concern us here. Children's readiness for the outside–in aspects of writing literacy begins in play and storytelling activities that do not explicitly involve the decoding or creation of text. One of the most important outside–in writing literacy skills is the ability to deal with decontextualized language (Snow, 1983), which includes the ability to maintain cohesion and reference (Gee, 1985; Michaels, 1986; Peterson, Jesso, & McCabe, 1999) through manipulating linguistic devices such as tense and temporal adverbs (e.g., *when*, *after*), connectives (*but*, *and*, *so*), and referring expressions (*she*, *one*) (Nelson, 1996). In fact, these markers are precisely what teachers look for in school-based discourse (Michaels, 1986). Storytelling is a perfect place for children to practice talk about the "then-and-there" (Scarlett & Wolf, 1979) as they learn to distance objects, actions, and feelings both in thought and in language (Nicolopoulou, 1996). Structuring experience as stories ("narrative thought") and telling those stories are skills that come naturally to children, who have "an abundant and early armament of narrative tools" (Bruner, 1990, p. 79).

This description counters the view that there are fundamental differences between speaking and writing that mean their acquisition is quite separate. Sulzby (1996) shows that children do not acquire oral and written language in a linear sequence, and that literacy is the result of co-occurring competency with both forms of language and the contexts in which they are used. For young children, encouragement to both produce oral language for an audience that requires sophisticated use of decontextualized linguistic devices, and to begin to write, may be the most successful approach to integrating the insights of emergent literacy into the classroom.

2.2. The role of peers: Making meaning together

The "somebody" for whom language is produced is often peers. Although parents certainly introduce the importance and possibilities of writing to children, through writing thank-you notes to relatives, grocery lists, and so forth (Hall, 2000), it is through interaction with peers that the conception of the other as audience, with its attendant demands for decentered and decontextualized language, matures. In emergent literacy, both the cognitive and the social roles played by peers are vital (Damon & Phelps, 1989). The interdependence between peers is unique in how it pushes children to take the perspective of the other and to function at a higher level than in other contexts. Vygotsky

(1978) proposed that peer interaction provides a "zone of proximal development" within which the behavior of a more competent peer can be beneficial to a younger peer. Piaget (1962) argued that among peers, difference in perspective leads to cognitive conflict, which, in turn, leads to cognitive restructuring and growth. Pellegrini, Galda, & Rubin (1984) proposed that difference in perspective is the key factor in play that affects children's literacy development. When two peers collaborate, the simple juxtaposition of their actions allows the peers to modify their understanding of their own actions, through appropriating the perspective of the other peer (Rogoff, 1991). That is, to apply Rogoff's (1991) notion to emergent literacy, the very fact of telling a piece of a story that follows after the piece told by one's peer allows both peers to gain a new understanding of the meaning of their words in the context of the story (Doise, 1990).

But peers can also serve quite explicit instructional roles with one another in literacy contexts. Neuman and Roskos (1992) observed children engaged in instructional conversation with a peer, negotiating, and coaching each other's literacy activities. Unlike the exchanges in adult–child instructional conversations, children instructing one another often reversed roles and attributed the role of the more capable peer according to the purpose of the play at hand. Similarly, Stone and Christie (1996) observed children helping each other by modeling, assisting, directing, tutoring, negotiating, affirming, and contradicting each other in literacy activities. In fact, these functions serve a concrete role for both parties: Engaging in peer talk that served a wide range of social functions (from asking questions and initiating text sequences to playing) has been observed to be positively correlated with the change toward writing in the third person (Daiute, Campbell, Griffin, Reddy, & Tivnan, 1993).

2.3. Metalanguage: Knowledge of language and its uses

Finally, essential for writing literacy is awareness not just of language but also of metalanguage. Metalinguistic awareness is the ability to attend to and reflect on the nature, structure, and function of language. Even very young children who are just learning to speak demonstrate a kind of metalinguistic awareness when they play with the sounds of language. By the time they are 2 years old, children begin to play with the words that make up language, often in "conversations" with themselves, when they are alone (Nelson, 1989). Slightly older children engage in similar behaviors, but in collaboration with others. Children of this age derive tremendous pleasure from rhyming words ("you silly," "no, you pilly") or words that sound similar (adult: "Indians lived in a teepee"; child: "pee-pee!"). Slightly more complex kinds of metalanguage that imply actual reflection on language, such as the use of puns, which demonstrate a metalinguistic awareness of the multiple meanings of words, have been shown to be important for reading and for written language development (Hiebert & Raphael, 1998). Around the age of four, children begin to acquire metalinguistic awareness of pragmatics—knowledge of different communicative contexts, and the ability to describe language (Shatz & Gelman, 1973). Children of this age begin to mimic accents and different speech styles. In fact, traditional "reading readiness" measures predict reading ability less well than children's use of more explicit metalinguistic terms such as *say*, *write*, and *talk* during their spontaneous preschool play (Pellegrini & Galda, 1993). Three- and four-year-old children's use of narrative perspective in "reading" a storybook has been correlated with later academic competence in math (O'Neill & Pearce, 2001). These terms, and others that introduce reported speech, or bracket instances of embedded language of one kind or another, are important in part because they demonstrate a growing ability to conceive of language as something that is produced by somebody for somebody.

2.4. Broadening the definition of emergent literacy

The particular features of narrative most often prized by teachers (e.g., explicit use of linguistic markers and logical sequences) are encouraged primarily in mainstream culture (Gee, 1985; Heath, 1986; Michaels, 1986). For example, traditional African American oral narrative does not depend on the restricted temporal and causal chain ordering conventions of "school-literate" narrative (Michaels, 1986). Yet genres of language play and of storytelling exist in all cultural contexts. Despite descriptions of the multicultural aspects of storytelling activities, and some descriptions of their link to children's literacy and other aspects of development (Labov, 1972; Lee, 1992; Miller & Hoogstra, 1992), virtually no attempt has been made to integrate their benefits into the classroom (see Pinkard, 1999 for a notable exception). Indeed, the specific kinds of language play demonstrated by African American children is sometimes devalued and belittled to such an extent that African American children lose their desire to participate in the classroom (Michaels, 1981). This is more the pity since, as Heath (1986) argues, an exposure to many different speech genres is essential for all children. Heath points out that no one speech genre is inherently more elementary than another, and all students could benefit from having exposure to many types of language activities and genres. And when teachers respect the different discourse and literacy practices of the home environments, children can be highly successful in school-defined literacy acquisition (Katsarou, 1992).

Many of the activities described as contexts in which literacy emerges are instances of play. Play among children of this age group involves the whole body, and yet when literacy-supporting technology is found in the classroom, it typically resides in a desktop computer where an individual child is placed in front of a computer monitor and a keyboard. This makes it difficult both for children to collaborate, and for them to involve their bodies in play. But non-screen-and-keyboard technology is important in scaffolding collaboration, and in encouraging verbal, nonverbal, and embodied aspects of children's language play. Research in educational technology has not, however, tended to look at the speaking–writing continuum, nor the benefits of storytelling. In the next section, some research that shares some of the goals of the present research will be reviewed briefly.

2.5. Previous relevant technological research

Technologies to support children's storytelling have become increasingly common. For example, Druin and her colleagues (Benford et al., 2000; Druin, Stewart, Proft, Bederson, & Hollan, 1997) have designed a number of interfaces for and with children that support children's storytelling play. Other technologies supporting storytelling include a puppet system in which children can act out plays (Hayes-Roth & Gent, 1997), a virtual environment constructed by children's narrative descriptions (Bruckman, 1995), a series of multimedia tools that encourage storytelling (Kim, 1995; Steiner & Moher, 1992), and collaboration among children in the construction of dramatic stories (Nijholt, Theune, Faas, & Heylen, 2003; Prada, Machado, & Paiva, 2000). Most of these systems rely on desktop computers, although some have begun to be embedded in everyday objects. In none of these cases, however, are the systems designed to elicit features of storytelling drawn from a theory of literacy development.

In addition, most previous technology-based work that has explicitly addressed literacy has concentrated on children's reading rather than their writing. For example, Mostow et al. (in press) found that over a period of 4 months, children who used an automated program that displayed stories on a computer screen and monitored their reading gained significantly more in passage reading comprehension than children using commercial reading software or engaging in classroom reading activities. In a somewhat different approach, Wiemer-Hastings (1999) developed a system that analyzes children's stories for coherence, purpose, topic, and overall quality of the text and then provides feedback through multiple animated characters.

In work by the Cognition and Technology group at Vanderbilt University (1998), children watched an anchor story and then made books that could be printed out to be read to peers and family. The project demonstrated gains in reading comprehension and in various measures of written story production such as word fluency, sentence fluency, and story complexity among high-risk low-SES first-grade children.

Some Intelligent Tutoring Systems (ITS) have examined the role of peers or partners in learning. For example, Chan and Baskin (1988) created a "learning companion," an artificial student who interacted with the real student while both learned under the guidance of an intelligent tutoring system. By including two tasks, learning by being tutored and tutoring, learning companion systems offered a learning protocol that is similar to "reciprocal teaching" (Palincsar & Brown, 1984) in which children take both the teacher's and learner's role.

In the Teachable Agent project (Brophy, Biswas, Katzlberger, Bransford, & Schwartz, 1999), children learned ecology by teaching a non-embodied agent about the subject. Brophy et al. (1999) found that children who studied to teach the agent did better on the posttest than control children who studied just for the test. Animated Pedagogical Agents (Johnson, Rickel, & Lester, 2000) are intelligent tutoring systems that have been given an embodied representation, which allows them to demonstrate visually how to perform tasks, and communicate using language, hand gestures, and facial expressions. In *T'rrific Tales* (Rix, Cooper, & Brna, 2001), a learning companion in storytelling aims to help the child acquire the key skill of emotional perspective in the task of narrative. Overall, however, empirical evaluations of systems that utilize images of agents have yielded mixed results.

Finally, toys play an important role in children's cognitive and linguistic development, and, in forcing children to reconcile their internal fantasy world with actual objects, toys can allow children to practice the skills of "symbolicization" and representation (Winnicott, 1971). For this reason, some educational technology has begun to move away from the desktop and focus on imbuing tangible artifacts with digital capabilities (Resnick et al., 1998). In a process that Scaife (in press) calls "external cognition," combinations of physical artifacts can encourage active learning as children interact with and reconcile the known and the familiar. In contrast to the simulation environments of the pedagogical agents, these tangible learning artifacts necessitate the use of motor schemata as well as linguistic ability. Of course, for technologies whose aim is literacy, it might seem paradoxical to avoid the keyboard. In this context, it is important to emphasize that SLS target *emerging literacy*, that is, those linguistic skills that are acquired by young children, and used in oral language, necessary before the mechanics of writing can come into play.

Although certainly not a new technology, a particularly intriguing result from a study looking at contextual effects on the production of narrative language demonstrated that stories children told over the phone were longer, more detailed, and more vivid than those told face-to-face (Cameron & Wang, 1999). Cameron and Wang (1999) suggest that the telephone encourages children to not decontextualize, but—more intentionally—*recontextualize* their language for an audience. Like the telephone, but unlike television, new digital technology can encourage active construction of language, and its mediating properties can be used to encourage metalinguistic reflection. It is for this reason that Story Listening Technologies can encourage children to make gains in language skills. SLS can encourage children to recontextualize their language for an interlocutor, in a way similar to that demonstrated by Cameron and Wang—whether that interlocutor be co-present or temporally/spatially distal, real, or imagined.

In sum, narrative is of paramount importance to literacy. To support emergent literacy, children need to author their own personally and culturally meaningful content in a way that is representative of the oral–written emergent literacy continuum, but that focuses them on key aspects of decontextualized language use. These goals can be achieved through storytelling and story writing, activities that are also important in children's broader cognitive, communicative, and linguistic development. Many schools are beginning to recognize the creation and manipulation of oral and written text as key aspects of literacy education. In parallel, teachers are being encouraged to incorporate technology into classroom activities. Technology, and particularly tangible non-screen-and-keyboard based technology that can support children's language play involving the whole body, may play a unique role in supporting emergent writing literacy and otherwise making a bridge between oral and written language, both in the classroom and outside.

3. A model for technology and literacy development: Story listening systems (SLS)

With few exceptions, previous work on literacy technologies has eschewed writing in favor of reading. Even within reading, most of these technologies approach literacy from the inside–out—graphemes, phonics, and punctuation—rather than the more social and functional approach. Technologies for literacy and for storytelling have been approached separately, and thus the personal and epistemological connections that can arise from constructing one's own language have been ignored (Resnick, Bruckman, & Martin, 1996), as has the possibility of using technology to bootstrap academic competence off of a skill that the child is already good at. Finally, technology to support the collaborative social and peer context of emergent literacy, such as pretend play or oral storytelling in pre- or nonschool contexts, has been under-explored. Technology of this sort would have to move away from the desktop screen–keyboard interface, since young children primarily engage in collaborative oral storytelling and fantasy play using their whole bodies, and may be considerably slowed down by the constraints of a keyboard and mouse. Overall, then, with rare exceptions, it appears as if technological innovation has not kept up with innovation in literacy learning theory, and that the four key features of the SLS literacy development model that have been underlined as important by researchers in non-technological approaches, have not found their way into technologies for literacy development.

A social context—a feeling of being understood, and having an authentic environment in which to pursue one's communicative goals—is necessary to support outside–in components of literacy. Of course, technology will never replace a genuine social context—peers and adults who care. The SLS model improves on current technology for literacy by extracting those aspects of the social context of peer interaction and of adult interaction that facilitate literacy learning, and use enabling technologies to perform them. Thus, the SLS model relies on two features of childhood and two features of new technology: children's inherent ability and desire to tell stories, which may contain within them the skills required for writing; the support that children provide to one another in the narrative play arena, which may be as good as, or even superior to that provided by adults; the ability of new technology to be removed from the old screen-and-desktop context; and its capacity to support children as producers as well as consumers of content.

By proceeding along these four axes, based on essential properties of childhood and possibilities of new technology, we can create an effective context for the acquisition of literacy skills. SLS share four essential traits: (a) they evoke storytelling from children, and use children's oral storytelling skills to bootstrap literacy, (b) they encourage peer play, and sometimes even embody peers as playmates **in** the system, (c) they do not require children to learn desktop screen–keyboard–mouse interfaces or to sit at a desk before they can engage in normal children's behavior; instead they are built into children's toys, and thus invite the kind of embodied play that young children engage in, and (d) rather than constraining the kind of stories that children can tell or listen to, they ask children to construct their own personally meaningful content. Systems that possess these four characteristics are expected to allow children to succeed at three crucial predictors of literacy: using decontextualized language, collaborating with peers to make meaning, and gaining metalinguistic awareness. They can also succeed at broadening the definition of emergent literacy in such a way as to successfully scaffold literacy for children whose pre-literacy behaviors do not fit the mainstream model.

One of the benefits of the approach is that the SLS allow abundant access to the child's process of storytelling—they allow, therefore, for study of the learning mechanism that underlies the SLS. Each stage in the child's interaction with the object is saved for analysis. As a result, comparison of children's uses of different SLS, and of SLS with other kinds of literacy instruction can be compared to evaluate each of the features that makes up the model, and thus evaluate the design features for literacy technologies.

4. Six Story Listening Systems

In what follows, three early SLS (*Renga*, *Rosebud*, *SAGE*) designed to experiment with the role that technology might play in children's storytelling are described. Next, information from three SLS (*TellTale*, *StoryMat*, *Sam*) that explicitly address the value of "toys that listen" for fostering children's emergent literacy skills are presented. These latter three systems target those aspects of language interaction that are a source of literacy-relevant and literacy-necessary skills. Finally, a description of exploratory work integrating SLS into the classroom is offered, including postulates concerning future work that supports children in an explicit transition from oral language to writing.

4.1. Renga

Renga (from the Japanese word meaning, "linked poem" or "linked image") was a storytelling project (Cassell, 1995) that encouraged children to add a sentence to an ongoing story on the web, and in doing so to become a part of a storytelling community. *Renga* focused children on the use of metalinguistic cohesive devices ("he" to refer to a boy, "and then," "but, at the same time" to link sentences), through peer collaboration while experimenting with the technical capabilities of the early World Wide Web as support for the social activity of storytelling. In our initial introduction of *Renga*, we invited the participation of every school in the world that had a web presence (214 schools, in October,

1995) to join us in the kind of round-robin storytelling that engages children in first grade classrooms. Teachers from 14 schools in 11 countries accepted our invitation and used *Renga* with their classes to collaboratively tell stories during one 24-hour period in October 1995.

Renga succeeded in supporting a kind of collaborative storytelling among children across distance, and succeeded in focusing children on the task of constructing local linguistic links between the sentences that they wrote, and the previous sentence on the page. But the nature of the collaboration was not inspired by personally meaningful content-indeed by any particular topic—nor did it have any overarching structure and so it typically devolved into rather unrelated sentences 100 or so lines down. We also found that children needed to communicate about themselves as well as the story, i.e., in the middle of an episode of the story one girl added, "Hi, I'm Tracy and I like icecream. I live in Australia. Does anybody else like icecream." The realization that children also needed to collaborate on community—on expressing who they were to one another—led us to change the format of the story and add a separate window where information about the author of each sentence was displayed as an index of *social presence* (Short, Williams, & Christie, 1976). In addition, there was no facility for rewriting, editing, reflecting on one's own language or the language of one's peers, nor was there any audience—any notion of who the story was written *for*. To address these limitations, we designed *Rosebud*.

4.2. Rosebud

Rosebud (Glos & Cassell, 1997) was a desktop computer system designed to evoke personally meaningful stories between 7- to 9-year-old children and their stuffed animals (via an infrared transmitter in the toy and receiver in the computer), support collaboration among multiple children, as well as to encourage the act of reflecting on one's writing. Regardless of whether highly "mediatized" figures such as Winnie the Pooh or anonymous figures were used, highly personal stories were told by 7- to 9-year-olds, as we can see in the following story told by a 9-year-old girl playing with a Pooh Bear and Eeyore animal:

> Once upon a time a very long time ago there were two friends named pooh bear and eeyore. They liked each other very much and let nothing get in there way. One day eeyore felt sad because his mother passed away. So he went to his good friend pooh bear to ask for advice. Eeyore asked pooh bear and pooh bear said to take it easy and relax. Eeyore said ok I will.

Although it was clear that the personally meaningful nature of the computer book's request for a story was motivational and led to a great deal of writing, children were not interested in rewriting—there was no reason intrinsic to the system for them to reflect on what they had written, and to rework it. In addition, children's frequent requests to record their stories in the stuffed animal to share them with their friends indicated it was important to move the interaction away from the desktop computer. To address these limitations, we designed several new systems, including the *SAGE* system, where the structures of discourse were explicit in such a way as to encourage children to be reflective about language use.

4.3. SAGE

The goal of *SAGE* (Storyteller Agent Generation Environment, Umaschi-Bers & Cassell, 1998) was to invite children to design their own ideal listeners, and in doing so to reflect on the speaker and audience aspect of storytelling. *SAGE* gave 10- and 11-year-old children a library of computer-based wise old sage storytellers to choose from, each of whom listened to the child's personal story and then responded with a relevant tale of his/her own. Children could choose to speak to a rabbi, and then choose a relevant story from a database of Hasidic tales; a Buddhist scholar who always had a relevant Tao proverb; or a French grandmother who replied with one of the fables from La Fontaine. Older children could also create their own sage storytellers and to design storytelling interactions for their peers.To support children as constructors as well as consumers of the storytellers, we implemented a visual programming language that allowed children to design and program the scripts used by the sage storyteller to respond to users, the conversational structure or flow of the interaction between the child storyteller and the sage storyteller, and the database of stories offered in response by the sage storyteller. Over the course of a weekend workshop, children became able to observe and repair breakdowns in conversational interaction, showing development of metalinguistic awareness in the process. For example, one child built a "wise old person" based on Shaquille O'Neal, the basketball player. In a demonstration of the system, when Shaq asked the child's father, "I guess you are around 11, am I right?" and the response was, "No, I am 45," the program crashed. The child quickly realized that he had not programmed a branching node to allow the possibility of a "no." He went back to the authoring mode and added the branching to the conversational structure. This process appeared to engage children in the exploration of notions of communicative decentering.

SAGE was also quite successful in encouraging reflection on the activity of storytelling—its structure and function. For example, the child who built a Shaq sage, carefully typed into his storyteller six of Shaquille's response stories from a book written by the famous basketball star, but he typed in the exact responses he thought the user might give to Shaq rather than decentering and programming possible responses other users might make. For instance, Shaq called one user "Bernie," although when the system asked her name she had responded, "Marina." The problem was not a computational bug, which he had earlier resolved, but a communication bug, due to Bernie's hard coding of his own name in all the system responses! Bernie had not decentered, i.e., he had not created an experience for users different from himself (Umaschi-Bers & Cassell, 1998). Our experiences with the *SAGE* system led us to turn our attention to younger children, systems that are simpler to use, and more explicit scaffolding of preliteracy behaviors.

4.4. TellTale

TellTale (Ananny & Cassell, 2001) was designed explicitly to engage children in the kind of discourse that bootstraps writing literacy. *TellTale* illustrates an important concept of writing by its form: units of discourse must hang together somehow, and then be connected to other units, and there must be a beginning and an end. It was developed to foster metalanguage, decontextualized language, and multiple types of discourse. *TellTale* is a caterpillar-like toy with five modular body pieces and a head. Children can press a button on each of the five body pieces to record 20 seconds of audio and press another button to play the audio back. The body pieces detach from one another and children can arrange and rearrange them in any order. At any point the child can attach the toy's head to the body to hear the entire audio story played in sequence. *TellTale* resembles the manipulatives that Resnick et al. (1998) have used to support children's exploration of math and physics.

4.4.1. Metalanguage

Initial observations of children playing with *TellTale* revealed that *TellTale*'s segmented body affected how children reflected on their story language and how they experimented with story structure. Four stories recorded one after another by one 6-year-old that illustrate this are shown in Table 1. The first story is a complete and coherent narrative. She only used two of the five body pieces, saying she "didn't need the other ones." In this first story, then, the form of the caterpillar played no role in the form of her story. In her next story this same 6-year-old used all five of the body pieces by putting shorter story segments in each segment of the caterpillar, which involved at least some advanced planning about the structure of the story.

The third and fourth stories were recorded in response to an experimenter's question about why the child liked or disliked *TellTale*. She responded that she liked "*TellTale* a lot because you can split things up in different ways—see?" and then proceeded with the third story—in which she predominately recorded a single word into each body piece—and the fourth story—in which she recorded a single clause into each body piece. Note that the fourth story is based on the third but conveys more information. The third and fourth story demonstrate this child's ability to reflect on the structure or segmentation of the story, and how to map it to the structure of *TellTale*, an example of metalinguistic awareness of discourse segmentation.

Table 1
An example of metalanguage development across a play session with *TellTale*

	Body Piece	Audio recorded into body piece
1st story recorded	1	Once upon a time there was a little boy who was sleeping. The next morning he lost his pet frog. Then he went looking and [with rising intonation]
	2	He looked in a hole and the dog looked in the beehive. He looked I think under a rock and an owl flew over. And then he was calling his frog's name. He fell into the river. He was looking and he said "shhh." Then he found his frog. The end.
	3	*Did not use*
	4	*Did not use*
	5	*Did not use*
2nd story	1	Once upon a time there was a unicorn. And he was so pretty.
	2	And when he touched its horn a jewel came. And he touched anything and a jewel came
	3	And then it lay and it wanted me to get on its back.
	4	Then I rode to its castle.
	5	And saw a real live princess. The end.
3rd story	1	Once
	2	Upon
	3	A
	4	Time
	5	There was a unicorn.
4th story	1	Once upon a time
	2	There was a unicorn
	3	Named Crystal
	4	And she liked to play hide and go seek with people. And she was a good person.
	5	The end

4.4.2. Decontextualized language

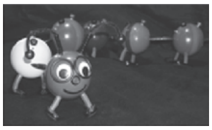
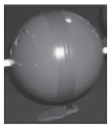
To look more explicitly at the development of an awareness of narrative segmentation and structural language, we constructed a control condition *TellTale* where only one piece recorded audio—100 seconds, the same total amount recorded across the five segments of the original *TellTale*. Fourteen children playing alone with either the control condition, unified *Telltale* (UTT), or the original segmented *TellTale* (STT) were invited to record stories in a room with no adult present. The transcripts were analyzed for the use of connectives and other kinds of macrostructure markers at the boundaries between body parts, following Peterson and McCabe's (1991) classification of local chaining and macrostructure markers. The findings are presented in Table 2 for the two different types of *Telltales*.

As the examples in Table 2 demonstrate, stories told with the STT were longer (an average of 72 words per story and 40.5 seconds per story) than those told with UTT (an average of 42.1 words per story and 34.2 seconds per story). The table entries also demonstrate that stories told with STT had fewer false starts than those told with the UTT, indicating that the segmented body pieces may enable children to plan their utterances off-line. Looking at recordings of Body Part (BP) #1 through #5 shows that stories told with STT also contained more conjunctive phrases ("and," "then," "however," "when," "while," "after," "later," "so," "therefore," "one day") per word (0.10 conjunctions/word) than those told with UTT (0.06 conjunctions/word). When conjunctive phrases did occur in STT, they tended to occur at body piece boundaries, indicating that children treated body pieces as story units, linking them with connectives.

In both UTT and STT conditions children tended to tell stories with classic beginnings (e.g., "once upon a time") but only in the STT condition did children also consistently finish their stories with classic endings (e.g., "the end"). Stories told with UTT tended to end in either false starts or long pauses indicating that children may have been having difficulty planning the next utterance.

TellTale's segmented interface, then, seemed to help children tell stories that were longer, more cohesive (containing fewer disfluencies and more conjunctions) and with more traditional beginnings and ends. The

Table 2
Examples of stories told with segmented *TellTale* (STT) and with unified *TellTale* (UTT)

Type of Story Listening System and Age of Child	
Segmented *TellTale*  (Child aged 6 years, 11 months)	Unified *TellTale*  (Child aged 6 years, 7 months)
BP#1: "Once upon a time there was a unicorn. And he was so pretty." BP#2: "And when he touched its horn a jewel came. And he touched anything and a jewel came." BP#3: "And then it lay and it wanted me to get on its back." BP#4: "Then I rode it to its castle." BP#5: "And saw a real live princess. The end."	"The caterpillar had just got home. He didn't know where he was. He asked the horse where his mother was. The horse said ...said he was ...she was ...at ... the ...leaves she ...it ...she said ..."

skills children practiced while playing with the segmented version of *TellTale* (planning, chunking, revising) are very similar to those that are required for written literacy. These findings suggest that, with respect to segmentation, *TellTale* encouraged children to tell oral stories in ways that are similar to how they will eventually construct written texts.

4.4.3. Multiple discourse types

TellTale does not restrict in any way the kinds of discourse that can be recorded. An evaluation carried out in two schools in Dublin, Ireland examined how *TellTale* might support the language play of children from different socioeconomic strata (SES). Specifically, this evaluation investigated the strategies that high- versus low-SES children used to establish cohesion in oral narrative. A total of 22 children participated: five low-SES dyads (10 children) and six high-SES dyads (12 children).

All children were invited to "tell stories with this storytelling toy." The children in the low-SES dyads were less likely than those in the high-SES dyads to tell complete stories and were more likely to record song fragments, dialogues, and rhyming sequences into the body pieces, or record an amusing quotation into each body piece (for example, 20% of utterances from children in the low-SES group were sung rather than spoken, as opposed to under 5% in the high-SES group). Children from both high- and low-SES groups consistently recorded utterances that contained story events (in both conditions, approximately 75% of all children's recordings contained at least one event). Children from both high- and low-SES groups also used connectives at *TellTale* body piece boundaries but children from high-SES consistently used more connectives (in 31% of their utterances, compared with 14% of utterances from the low-SES group). In terms of the process of telling stories, both high- and low-SES children incorporated both narrative (characters, places, actions) and syntactic (exact word phrases) aspects of their partner's utterance into their own. But low-SES children tended to make incorporations simultaneously (i.e., during co-occurring recordings), whereas high-SES children tended to incorporate each other's content across consecutive recordings; co-occurring contributions constituted 31% of utterances in the low-SES group, as opposed to 4% of utterances in the high-SES group. Children from both high- and low-SES groups showed cohesion with the previous child's segment through paralinguistic means (e.g., rising and falling intonation) and nonverbal means (e.g., gestures and eye-gaze). But children from the low-SES group used cohesive linguistic devices less often; they used more paralinguistic and nonverbal strategies, rather than explicit connective chaining with the previous child's segment.

Overall, children from different socioeconomic strata tended to engage in slightly different behaviors during collaborative storytelling. An initial interpretation may be that low-SES children's high percentage of co-occurring utterances and low percentage of syntactic connectives indicates that they were aware of their co-participant and less able to engage in good turn-taking behavior. However, this may not be the case for two reasons: children from the low-SES group used non-syntactic, paralinguistic, and nonverbal strategies to indicate cohesive chaining during story construction. Also, despite the high percentage of co-occurring utterances in low-SES children's recordings, these children consistently incorporated elements of their partner's utterances *simultaneously*. Children from high-SES tended to establish coherence using syntactic connectives between consecutive recordings. Because *TellTale* supports multiple discourse types, children were able to use it to support different narrative styles. In turn, the children's use of *TellTale* demonstrated that narrative styles across socioeconomic strata are equally concerned with cohesive chains, and attention to social collaboration, despite the fact that not all of these forms are equally accepted in classrooms.

4.5. Storymat

Like *TellTale*, *StoryMat* was entirely removed from the desktop. However, *StoryMat* provided children with virtual peer collaborators as well. *StoryMat* was a soft cloth quilt with appliquéd figures on it—a familiar toy for young children, one that evokes narrative and whole-body play. Squeezing one of the small stuffed animals provided with the quilt triggered the recording of the narrating child's voice along with the two-dimensional coordinates of the stuffed animal location. When the child let go of the stuffed animal, the coordinates and the voice were combined into a movie file and saved in the computer to be played at the appropriate location on the mat (See Fig. 1). When new input was subsequently encountered at the same place on the mat, the movie file was automatically played back via a projector mounted above the mat, and heard through a pair of speakers next to it. The current child could then tell her next story. Sometimes she might come up with a continuation of the story she just heard. Or she might continue telling her own story, incorporating some story elements from the story she just heard. In this sense, *StoryMat* is a kind of imaginary playmate (Taylor, 1999), but one who also mediates collaborative storytelling between a child and her peer group.

StoryMat (Cassell & Ryokai, 2001; Ryokai & Cassell, 1999) was designed to encourage exactly the aspects of 4- to 6-year-old's collaborative reciprocal storytelling that have been shown to be related to later literacy (Dickinson & Tabors, 1991). In *StoryMat* the voices of previous children who have played with the toy serve as peer collaborators, motivating children to continue producing narrative language, and providing a kind of virtual audience for the children's words. We hypothesized that even so thin a representation of a peer as a disembodied voice would, as described by Dyson (1993), imbue the child's symbolic acts with social meaning in such a way as to drive the acquisition of those acts of symbolization.

Our evaluation of the *StoryMat* system concentrated on three kinds of emergent literacy activities among early school-age children. First, symbolic transformations of real objects into fantasy story objects were considered important because of the link between symbolic transformations and later

Fig. 1. Child engaged in storytelling with *StoryMat*.

writing literacy (Pellegrini & Galda, 1993). Second, incorporations of story elements from the story of a collaborating peer were targeted because of the increased complexity found when children incorporate aspects of each other's stories (Corsaro, 1992), and the role played by peers in encouraging more sophisticated linguistic devices (Bokus, 1992). Third, the use of different narrative voices was assessed because of the essential role of perspective-taking in the development from oral to written literacy (Peterson & McCabe, 1983), and the specific role of narrative voice in acquiring more sophisticated kinds of story structures (Auwarter, 1986). These decontextualized language measures were taken from the body of work cited here and are all well validated.

Thirty-six children between the age of five and eight participated in the evaluation study. Children were randomly assigned into one of two groups: (1) a *StoryMat* group, who played on *StoryMat;* and (2) a control group, who played on an identical mat, without the responsiveness (the "passive mat"). In each group, 6 participants played alone and 12 participants played with another playmate, resulting in six dyads and six singles in each group. In all conditions, the instructions were fundamentally the same, "Let's pretend that we are living in this world. Will you tell me stories that happen in this world? First I'll play with you some. But I'm going to leave the room in a little while so that you can be alone to tell your stories on the mat." Children in the *StoryMat* condition were given one additional instruction: "Do you see a button here? (The button on the stuffed rabbit was shown). You have to hold down the button while you tell your story so that the mat knows you are telling your story. And you let the button go when you are done so that the mat knows you are done with your story."

The experimenter always told the first story, and in the *StoryMat* condition the experimenter then sat and listened to the story that the mat gave back in reply. In all conditions the child was then invited to tell a story, and then the experimenter left the room. Thus, in both conditions children heard an equal number of practice stories before the actual session began. No additional instructions were given as to the functioning of the system or what was expected of the child. The experimenter was absent for the entire play session, as it is well documented that children interact differently with one another when they are in the presence of adult observers (Hickmann, 1985). The mean time of interaction of each child with the system was 15 minutes, but play began to degenerate after about 10 minutes, and so the first 10 minutes of discourse from all 36 children was transcribed, giving a total of twenty-four 10 minute sessions (12 single and 12 dyad sessions).Three dependent variables were examined, operationalized according to previous literature: (1) the sophistication of children's fantasy play was operationalized by counting the number of real objects in the environment that children transformed into fantasy objects (Preece, 1992), for example calling the green space on the quilt a "golf course"; (2) the quality of the collaboration between child and mat was operationalized by counting the number of times children incorporated an element proposed by *StoryMat* into their ongoing story (Preece, 1992), for example when the *StoryMat* gives a story about a boy playing a music box, and the child's subsequent story talks about a magic music box; (3) the sophistication of narrative play was operationalized by assessing the number of narrative roles taken by each child (Auwarter, 1986). Thus, character role is distinguished by speaking as one of the story characters ("Ahh, what a beautiful day! I think I'll go for a walk"). Narrator role is distinguished by describing what the characters say ("Then the bunny exclaimed what a nice day it was"). Metanarrator role is distinguished by acting as stage manager, and deciding what the other characters should do and say ("Ok, you be the bunny and you say you want to go for a walk").

A 2 (Mat type: *StoryMat* vs. control condition) × 2 (Number of children: single vs. dyad condition) analysis of variance applied to the number of symbolic transformations demonstrated a main effect for mat type $F(3,20) = 9.7$, $p < .01$, with no other significant main or interaction effects. Thus, *StoryMat* encouraged more symbolic transformations in the children's stories than the control condition, *M*s (*SD*s) = 9.42 (3.78) and 2.59 (2.31), respectively.

A similar 2 × 2 ANOVA conducted on the number of incorporations of words and themes revealed an interaction between mat type and number of children, $F(3,20) = 3.49$, $p < .05$. As shown in Fig. 2, dyads playing on *StoryMat* incorporated words and themes most often, but children playing alone on *StoryMat* incorporated as many elements into their stories as did children playing with peers on the passive mat. This finding provides evidence for the fact that the *StoryMat* functioned similarly to a real co-present peer in encouraging collaboration on the content of fantasy.

Finally, as the frequency of children serving in different roles reported in Fig. 3 demonstrates, children playing on *StoryMat* took the more advanced role of narrator, rather than character, more often than the children in the control group, $F(3,20) = 3.49$, $p < .05$). Given that the narrator and metanarrator roles promote perspective-taking, some of the advantages that accrue to children playing with peers, then, are likely to occur for those children playing with the *StoryMat* system, even when peers are not present.

This aspect of narrativity is particularly important for two reasons. First, the ability to shift among narrator, character, and metanarrator roles is just being acquired in the preschool to early-school age range that was examined in our study. Second, perspective-taking is thought to be an essential bridge from oral

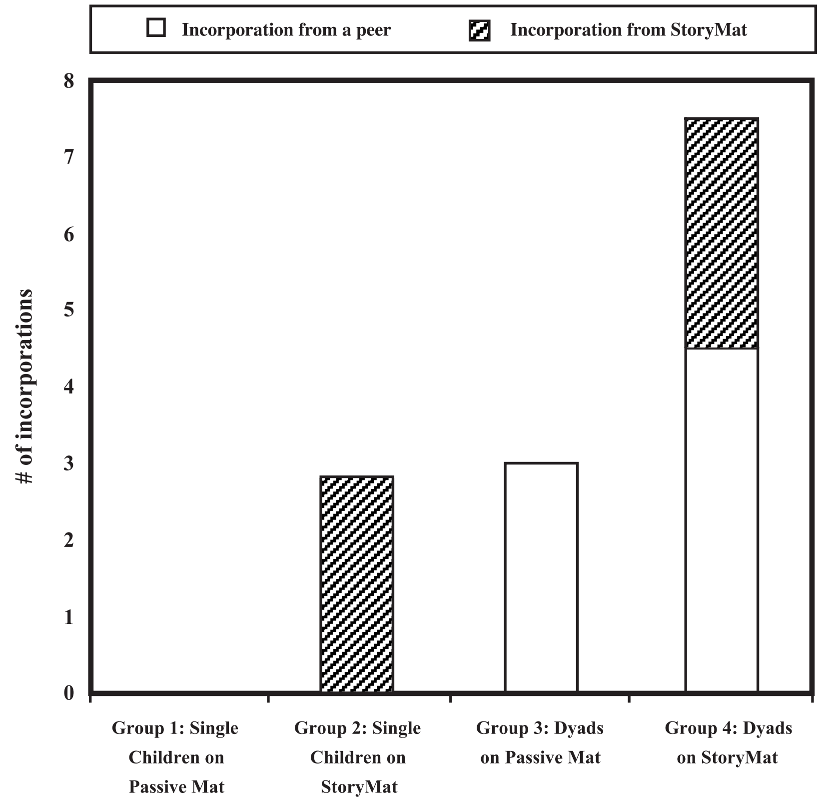


Fig. 2. Frequency of incorporating elements from other children's or *StoryMat*'s stories by children playing alone or in dyads.

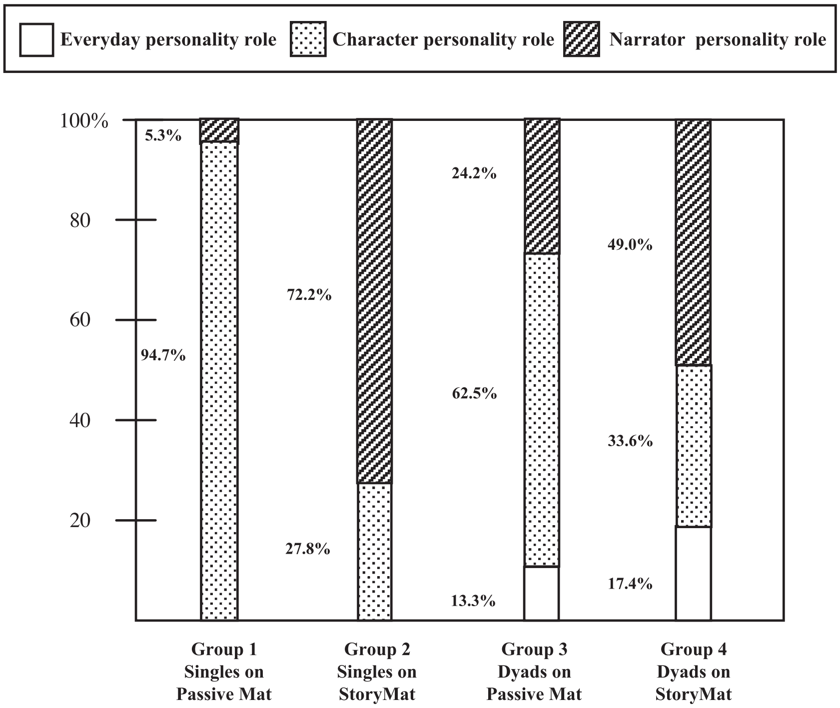


Fig. 3. Children's use of narrative roles as a function of number of children playing on the mat and the type of mat (passive vs. *Storymat*).

to written literacy. When children first begin to write stories it is hard for them to realize that their listeners will not share a joint context and cannot see their hand movements or hear their voice changes. Narrative perspective is how mature storytellers set this context for their listeners. As explained by Scarlett and Wolf (1979) and Traugott (1979), storytelling with a narrating voice allows others to understand the intention of the author. It enables the audience to construe what is happening in the story. The results suggest that StoryMat creates an environment where a child is encouraged to engage in this kind of mature audience-focused storytelling and, in Cameron and Wang's (1999) terms, *recontextualize* information in exactly the way that literacy will require of them.

The SLS discussed thus far incorporate some implicit aspects of peer support for narrative performance. However, they contain no embodied representation of the other virtual children with whom the child is playing. Embodied Conversational Agents (ECAs) can serve this role. ECAs are life-size humanlike graphical computer characters projected on a screen that are able to engage in face-to-face dialogue with a user, using not only speech but also nonverbal modalities such as gesture, gaze, intonation, and posture (Cassell, Sullivan, Prevost, & Churchill, 2000). We have constructed several such systems that use machine vision and speech recognition to sense the user's speech, gesture, body posture, and intonation, and use models of the relationship between verbal and nonverbal behavior to make the animated computer character respond appropriately. Our research on ECAs has begun to serve the goals of our research on SLS as we have developed the notion of shared reality in which virtual collaborators can share real objects with their human users. This is the case for *MACK*, an animated embodied robot in a kiosk who can share a real map with users, and for two recent SLS that we have built. The first is

GrandChair, a virtual grandchild who elicits life stories from seniors. Speech recognition and sensors in a rocking chair that the user sits in allow the virtual grandchild to give appropriate feedback, while the system videotapes the stories for later viewing by the senior and his/her family (Smith, 2000). The second is *Sam the CastleMate*, described in the next section, a virtual peer designed to engage in particular kinds of storytelling play with children.

4.6. Sam the CastleMate

Sam the CastleMate (Cassell et al., 2000; Ryokai, Vaucelle, & Cassell, 2003) involves all four traits of the Model for Technology and Literacy Development. Sam was designed to encourage children to produce decontextualized language and metacognitive reflection in the context of peer storytelling by modeling and scaffolding the child in those activities, and inviting the child to scaffold and coach in return. Sam is a virtual child who invites children to participate in collaborative and conversational storytelling play with real toys. Sam is projected on a screen behind a castle, and can both listen to a child's stories and tell her own (see Fig. 4). A toy figurine that can exist in either the physical world or on the screen allows Sam and the child to pass the story back and forth between their worlds.[1]

When a child arrives in front of the toy castle, Sam looks at the child and says, "Hi, I'm Sam!" After the child greets Sam, Sam tells a story as Sam moves the figurine around the castle, occasionally looking up to draw the child into the story. When she finishes her story, Sam says, "I'll put the toy in the magic tower so you can tell a story," and places the figurine inside the tower. When the child opens the door, she finds the figurine Sam had been playing with and the child tells her story. While the child does so, Sam watches the child (following where the child is moving the figurine with head and eye movements), nodding, smiling, and prompting, "And then what happens?" When the child is done, she places the figurine back in the castle where Sam can access it.

Sam then starts her story in the same part of the magic castle where the child finished hers. Sam tells stories using more advanced forms of linguistic expressions (quoted speech, and enough temporal and spatial information for the audience to be able to reconstruct the story). In Vygotsky's (1978) terms, children learn through their participation in activities that are slightly beyond their competence, with the assistance of adults or more skilled children. Thus, by interacting with a peer who tells stories in a developmentally more advanced form than the child, the child may enter his/her zone of proximal development. Our hypothesis was that by interacting with a slightly more advanced peer, children would learn from Sam's linguistic behavior and therefore, perform their storytelling task in a more mature form themselves. However, in addition, Sam's young appearance and playful environment may invite children to critique Sam's behavior, giving them an opportunity to externalize their thoughts and communicate

[1] The *Sam the CastleMate* system detects a child's presence through a microphone and a mat that senses the child standing in front of the castle. When the child is playing with the toys and narrating, the system uses audio threshold detection to determine when to give feedback (backchannels such as "uh-huh" nods, and explicit prompts such as "and then what happens?"). RFID tag readers are embedded inside of every room in the castle. The tag attached to the figurine tells the system in which room in the castle the figurine is located. A switch in the door tells the system whether the figurine is inside of the magic tower and when the magic tower door is opened, so that the child will never see the physical and virtual instantiations of the toy simultaneously (when the door is opened and Sam has the figurine, it disappears instantly and Sam expresses surprise). To make Sam's character believable, Sam's stories and other utterances were recorded from a real child, as the quality of children's synthesized voices is still poor. The software is written in Java and C++ and can run on a single PC with a graphics acceleration card. The animation is shown on a large display behind the castle.

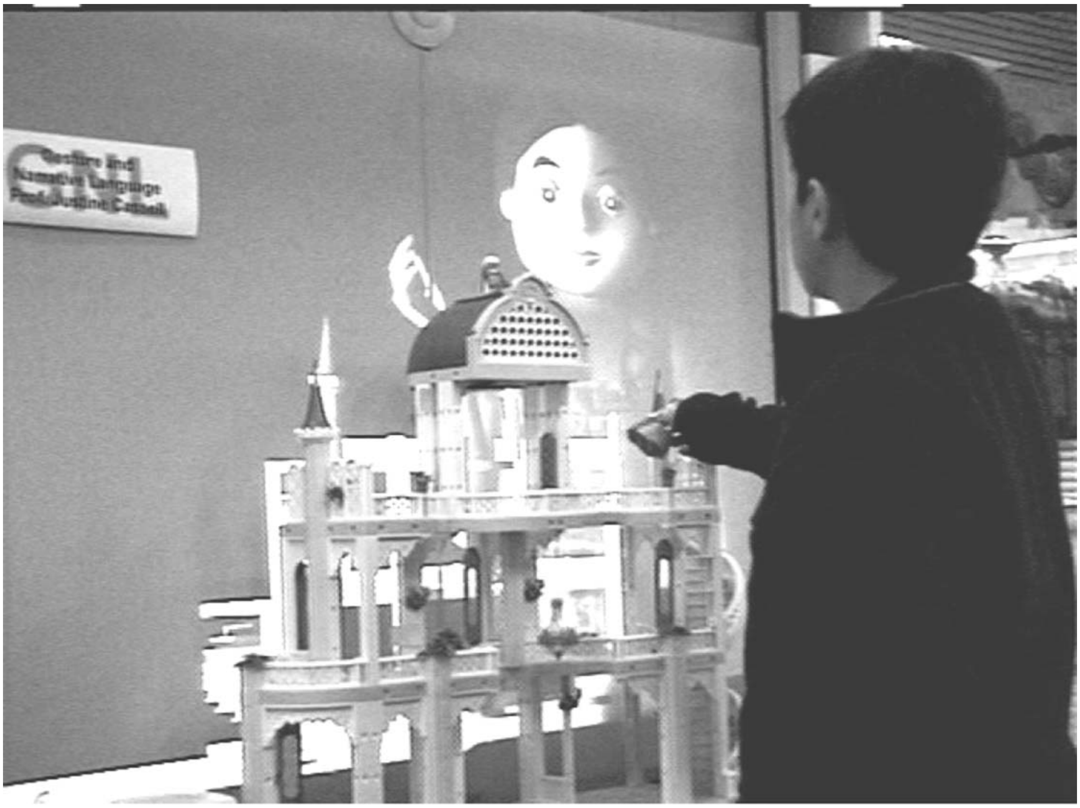


Fig. 4. Collaborative storytelling of a child with *Sam the CastleMate*.

their points using language. Our intention was for Sam to provide just the right amount of challenge. Sam's storytelling is more advanced than the child's, but not too advanced. Sam is a partner who is just a head taller than the child.

The effect of Sam on collaborative peer-like metalinguistic behavior and use of decontextualized language in children 4 years 6 months to 5 years 6 months was studied using a 2 (Number of children: singleton children vs. dyads) $\times$ 2 (Type of interaction: castle with Sam vs. castle without Sam) design. Twenty-eight children were videotaped interacting with the castle: 8 children played alone with a castle without Sam, 8 children played alone with a castle with Sam, 6 children in dyads with a co-present playmate with a castle but without Sam, and 6 children in dyads with a co-present playmate with a castle and with Sam. All children came from a mixed ethnicity, mixed socioeconomic status public school in one of the towns outside Boston. Only girls participated in this particular study, as the version of Sam that they played with employed a pink castle, and some boys did not wish to participate for that reason.[2] The experimental procedure was identical for all conditions. The castle and figurines, whether or not Sam was present, were introduced in the following way: "This toy is good for telling stories. See the castle? And the little toy? You can use these to tell stories. Ok, do you want me to show you? I'll tell a story with the toy, and then you can tell a story." In the Sam condition, the experimenter added "That's

[2] The current version of *Sam* plays with a wooden castle, and this problem has been alleviated.

Sam. Sam likes to tell stories and listen to your stories. Sam knows that it is my turn to tell the story because I will take the toy from the magic tower.'' The experimenter finished the instructions by saying, ''Tell as many stories as you like [in Sam condition, adding ''with Sam''] and then come and get me.'' For the remainder of the session, the experimenter remained outside the room, while a video camera recorded the child. The study was done in a ''Wizard of Oz'' setting where Sam's response was controlled by a researcher behind the screen. All children played for approximately 15 minutes: 5-minute introduction with an experimenter, and 10-minute play session on their own.

The children's 10-minute play sessions were transcribed by a team of two researchers who coded the occurrence of spatial expressions, temporal expressions, and quoted speech in the children's stories. Following Peterson, Jesso, and McCabe (1999), a spatial expression was coded as definite information about *where* the event took place (e.g., ''then the boy went to the *kitchen*'') and temporal expression as explicit information about *when* the event took place (e.g., ''he went downstairs *when he heard the noise*''). For the quoted speech, frequencies of both direct speech with a framing clause (e.g., ''then she said, 'Oh no!''') and indirect speech such as ''he said that he wasn't hungry'' (Hickmann, 1993) were coded. The occurrences were tallied, and then normalized with respect to the child's total storytelling time yielding a proportion score, i.e., the ratio of frequency of occurrence of each category per second of storytelling.

Children's play with Sam was striking in its naturalness. The children clearly enjoyed playing with Sam, and appeared to enter into the game of playing with a virtual peer, perhaps from previous play with puppets, or from experiences with imaginary playmates. The children did know that Sam is a toy; as one child remarked: ''[Sam's] more complicated because like you have toys that like do only like one thing—Sam does a lot of things. He tells different stories—not that many. It's way complicated.'' And they were clearly thinking about exactly what Sam was; as another child asked ''Can you make copies of Sam with the copy machine?''On the other hand, they were still engaged with Sam as a play partner and concerned that Sam listen to them, as demonstrated in the following interaction between a child and the experimenter. In this instance the system incorrectly sensed that the child had left, and so Sam went through the farewell part of the interaction, which led the child to fetch the experimenter from her observation post outside the experimental room:

CHILD: Sam said bye. He said bye to me and left.
ADULT: Uh oh. I wonder what that means.
CHILD: Sam's gone.ADULT: Sam's gone. Let me see if I can fix it. That's what happens with computers. Sometimes things break.
CHILD: But, he wasn't listening? Was Sam listening?

The children who played with Sam, either by themselves or with another child present, tended to tell a number of complete and fairly long stories. This is in contrast to children playing by themselves in the absence of the Sam virtual peer, who may very well have been telling themselves silent stories, but who did not vocalize those stories. These children became bored quite quickly, and often started to take the castle apart (also a problem when two children played with each other, without Sam).

But a complicated toy, even an open-ended one, does not suffice in literacy development. And if children playing alone do not engage in literacy practice, then one might ask why not simply provide children with peers, since peers have been demonstrated to be important in emergent literacy? An example of two children playing with the castle (and without Sam) is presented next. It serves as a baseline story between peers and provides a partial response to the question posed about the impact of peers on emergent literacy behaviors.

CHILD 1: It hangs there—
CHILD 2: Do you want me to do it?
CHILD 1: No, I can.
CHILD 2: She said nothing's going to move for it.
CHILD 1: But I'm just scared,
CHILD 2: I am, too. Let's turn on the lights. Now you won't be scared.
CHILD 1: Because ghosts do not like light, right?
CHILD 2: No.
CHILD 1: You broke this after I had fixed it.
CHILD 2: Not me.
CHILD 1: It's probably the ghost.
CHILD 2: There's no such thing as monsters. Did that door just open, or was it just my imagination?
CHILD 1: It was just your imagination.
CHILD 2: No. I think it was just the wind. I'm having nightmares.
CHILD 1: Me, too.
CHILD 2: I want to sleep. I want to sleep. I hope I am.

In this interaction there was a seamless transition between off-topic talk (as the children broke, and attempted to fix, the chandelier in the toy castle) and first-person narrative talk as the two children played at being friends in a haunted house. Knowing which segment of talk fulfills which function requires access to the physical context, as the children were not using explicit contextualizing cues. This kind of conversation is not a negative event, as it's perfectly comprehensible to all participants. On the other hand, it is not demonstrating the kinds of decontextualizing storytelling behaviors that are correlated with literacy skills. The contrast of this peer interaction to one involving a child alone playing with Sam, the virtual peer, is readily apparent:

SAM: Today, I'm gonna ride horses in the meadow! My dad, the king, said I can ride the, my big horse named Star. Oh no! Star has been stolen. I'd better go tell the sheriff. Oh, sheriff, my favorite horse Star has been stolen, I don't know where she is. Oh, no. No need to worry. The kind old lady from the other side of the forest has brought her back. And she's just coming back now. Whoopie! Thanks. Come on Star!

CHILD: Once there was a little prince. His mom and dad were really, really rich. That's what made them the king and the queen. He liked his life so much. He got a really fancy bedroom with a big window that was so high up he could see the whole entire land. One day he really wanted to do something. He went downstairs so he could ask his mother what there was to do. He said, Mom, what can I do? Then his father came into the room and they had a big surprise for him. Well, dear, we got more money so that means you can do whatever you want to do. Do you have any ideas of what you want to do today? Well, I want, I've always wanted to have, I've always wanted to have very, I've always wanted to have a crown. Cause. Well, we can get you one. Do you have anything else that's so much fun? Well, I want, today I want to learn how to do Irish step dancing. Cause St. Patrick's Day is

Table 3
Mean (*SD*) occurrence per story of three types of decontextualized language by children playing alone with Sam as a function of successive exposure to stories told by *Sam the CastleMate* (n = 8)

Sam's story	Type of decontextualized Language		
	Quoted speech	Temporal markers	Spatial markers
First	0.50 (0.57)	2.00 (0.82)	2.00 (0.82)
Second	0.50 (0.57)	4.75 (2.36)	7.50 (2.08)
Third	3.00 (1.63)	4.25 (3.20)	7.50 (2.08)
Fourth	2.25 (2.87)	2.50 (1.29)	5.75 (2.50)

coming up and I want to do some of that to entertain you. Well, OK. They got him a crown, then they went to a class where he could learn how to do Irish step dancing. And he learned everything. And on St. Patrick's Day when he woke up he not walked down the stairs like you usually do to be careful, he ran, ran and then he tripped and then he fell and then he started crying. Then his mom and his dad took him to the hospital and the doctor said he broke his leg. That meant he had to stay in his bed and he couldn't do Irish step dancing. So he was really sad. But then he got an idea. Probably he could show his mom and dad how to do Irish step dancing. Like draw all the steps and how he did it. Because he had a magic potion, so he put spells on his pictures and the pictures showed his mom and dad how to do Irish step dancing. Then he went upstairs and went into bed and closed the door. The End.

Note that this child's story continues Sam's theme of a king and his child, but then launches into topics that clearly come from the child's own life or imagination (Irish step dancing). Many of the children who worked with Sam continued themes from the Sam story that they heard. In addition, this child's story is well constructed, uses third person narrator voice and embedded reported speech for several different characters, and includes evaluative comments ("so he was really sad"). In fact, the majority of children playing with Sam told stories in the third person, despite the fact that Sam did not model that, while the majority of children playing with another child, without Sam, told stories in the first person, reflecting our earlier findings with the *StoryMat* system.

The children's stories were also analyzed for the occurrence of some sophisticated decontextualized devices: explicit spatial expressions (e.g., "then the boy went to the *kitchen*"), temporal expressions (e.g., "he went downstairs *when he heard the noise*"), and quoted speech (e.g., "then she said, "Oh no!"" or "he said that he wasn't hungry"). A 2 (Number of children) × 2 (Type of interaction) multivariate analysis of variance was conducted on the frequency (ratio) of quoted speech, temporal markers, and spatial markers per second evidenced by the children. Results demonstrated that the presence of Sam as a storytelling partner significantly increased the frequency with which children used quoted speech, $F(3, 24) = 10.58$, $p < .005$, temporal expressions, $F(3, 24) = 30.52$, $p < .001$, and spatial expressions, $F(3, 24) = 68.05$, $p < .001$. No effects involving number of children were significant. This suggests that Sam succeeds in evoking decontextualized language even in the presence of a real flesh-and-blood playmate.

Were the children's uses of literate expressions attributable to the fact that Sam modeled these behaviors, or simply due to the amount of time spent telling stories[4]? As can be seen in Table 3, with each subsequent

[4] In order to examine this question, we looked at whether the literate expressions increased over the course of the interaction with Sam, and over the course of interaction with another child. Remember that as the children took turns with Sam, every one of their stories was preceded and followed by a story by Sam.

story by Sam, children in the "one child with Sam" condition used more decontextualized language and metalinguistic expressions with increasing exposure to Sam's stories. Pearson product–moment correlation coefficients showed that with increasing exposure to Sam's stories, the children's use of spatial expression increased significantly, $r(6) = 0.35$, $p < .05$, and the amount of quoted speech approached the level of significance, $r(6) = 0.27$, $p < .06$). There was no relationship between increasing exposure to Sam's stories and number of temporal expressions used by children ($r = .07$). However, if one looks only at the first three stories, the use of temporal expressions also increases significantly with successive stories. For children playing in dyads without Sam, a *negative* association existed for the use of spatial markers and how many stories the children told, $r(6) = -.59$, $p < .01$), and there were no significant results for other types of literate expressions. It appears, therefore, that storytelling with Sam resulted in an increased amount of decontextualized language for children, an effect unlikely to be due to the simple fact of practicing storytelling.

For those children who did tell stories in the first person, many appeared to be explicitly continuing one of Sam's stories, as in the following example:

SAM: OK, my turn. I'm going to have a party and I'm going to invite whoever I want. My mom, the queen said I could. Oh look! Here Chris comes. I'm going downstairs to meet him. "Hi Chris, you're the first one here. What do you want to do?" "Well, we can go ask the mirror, who is going to come to your party?" "Oh yeah. Oh, mirror, who is going to come to my party?" "Oh, people from all the way over the land." "Oh yeah. Here, I see Cheryl, Brad, and Sean. Oh, this is going to be a great party." I'll put the toy in the magic tower so you can tell a story.

CHILD: La, la, la, la. Oh, it's my birthday today, and mommy and daddy are going to be out. I better get setted up. Da, da, da, da, da. Dee, dee, dee, dee. Uh oh.

SAM: And then what happened?

CHILD: I see my friends coming. I need to set up the party still. Oh no. Hi friends. Where's the party. Oh, I haven't set it up yet. Would you help me? Sure. I'll watch. Now tell me, my friends are they coming or not. Da, da, da, da. The yummy dessert is on the table. Where's my [XXX]. OK. Coming up. See any friends yet? Yup. I see Carla, Meg and Sheg. That's everyone I invited and you. Oh. This is going to be a great party. What's with the present? Oh no. I forgot it. I can run home and get it. I'll let the others in. Oh hi, friends. Yeah, I know I'm late. Where's the [...]

The continuation of themes from Sam's story is not the only kind of collaboration that was apparent in the interactions. Children in the single condition seemed to engage in peer-like collaborative interaction with Sam, talking as they might with another child, in particular as they might with a slightly younger child:

CHILD: You done, Sam? OK.

SAM: I'll put the toy in the magic tower so you can tell a story.

CHILD: What should I tell, Sam? Do you have an idea? Hmmmm.

SAM: Tell me a story.

CHILD: Oh, the girl was happy. She came back from-her husband was there, she was very happy. Everyone, I mean everyone knew she was a good girl. She always had fun playing with her sisters.

CHILD: You're silly, Sam!

SAM: I'll put the toy in the magic tower and you can tell a story.

CHILD: Hey Sam, want to talk about like where are we from? OK? Sam, I'll tell a story that's really cool, about where I'm from.

SAM: Cool.

CHILD: Once there was a girl, her name was Simone. That's me. She went to the house, she loved it, and then she married a boy named Sam. Oh, sorry Sam, I messed up.

In fact, children asked Sam to continue their stories, and even coached Sam in storytelling, much as if they were engaging in reciprocal instruction (Palincsar & Brown, 1984), and in line with Stone and Christie's (1996) description of peer interaction around literacy activities:

SAM: Cool. OK, my turn. One day me and my friend were playing around and we heard this loud cry [...] I'll put the toy in the magic tower so you can tell a story.

CHILD: [talking to Sam] Try to make a longer story next time. It's like this. The little boy was outside. He flipped all around and he went inside, he did a flip [...].

Children's behavior in the dyad with Sam condition allowed us to examine the effect of Sam on children's prosocial collaborative behaviors with one another. And, in fact, more prosocial behavior was seen than when two children played without Sam, and we observed more instances of explicit storytelling. Both effects are illustrated in the following example:

CHILD 1: Once upon a time there was a girl named—

CHILD 2: What about Anna?

CHILD 1: And the mom and dad went to a store. She could do whatever she wanted. So, she built everything. She went down the stairs, and then she broke the lamp. And then she messed everything up. And she jumped and jumped all over the place. And then she looked in the magic mirror and said, when is my mother and father coming home? And the magic mirror said, they're coming home right now. And she ran upstairs.

CHILD 2: Wait a minute,

CHILD 1. We can go upstairs.

CHILD 1: And she ran upstairs. And she ran upstairs again. So, they didn't find her. And then they were surprised that it was all messed up. And they didn't even know who it was from. So, then, she came back down. And they said, Annabelle. Did you do this? And she said, no. And she was lying.

CHILD 2: So, her nose went big?

CHILD 1: So, then, the mother and father put her bed.

CHILD 2: Because she lied?

CHILD 1: Because she lied, and because she wasn't supposed to do that.

CHILD 2: OK. My turn.

CHILD 1: Sammy—I want Sammy to do it. I'll put it back. [CHILD 1 puts the toy in the magic tower for Sam to take her turn]

In sum, children modeled their stories after Sam's, but also told stories as explicit models for Sam to follow. In doing so, children engaged in decontextualized language use, and metalinguistic comments about storytelling. Children engaged in prosocial constructive collaboration with Sam, and more often engaged in those types of behaviors with other children when in Sam's presence. In this sense, Sam is acting much like the Vygotskian more capable peer (Vygotsky, 1978), seeming to push children to act at the top of their individual abilities through the nature of their social interactions. It is not coincidental, of course, that social interaction be so important to the acquisition of literacy. As discussed above, the outside–in component of literacy requires "recontextualizing" one's thoughts so that they make sense to another (Cameron & Wang, 1999). Talking to Sam, like talking to a slightly older child, or a stranger, appears to require more top-down structure and reflection, and to push children to use grounding devices (devices to ensure and establish common ground) in their talk. Children's interaction with Sam demonstrates that social interaction, even with a virtual peer, can support individual development in the domain of language use and collaborative behavior.

What is the mechanism that underlies Sam's success in fostering these emergent literacy skills? To address this question we looked at the nonverbal behavior of children interacting with Sam, and of children interacting with another child. Most striking was the children's turn-taking behavior, as revealed by their eye gaze. Sam forced turn-taking behaviors with children, and because taking storytelling turns is the only way children could interact with Sam, the children in the "one child with Sam" group demonstrated turn-taking behaviors with Sam beautifully. Four independent sample t tests were conducted on the number of times that children interacting with Sam versus interacting with another child shifted their gaze (1) to Sam/child peer when Sam/other child was telling a story, (2) to Sam/child peer when Sam/child peer gave the child back the toy and relinquished the turn, (3) to the castle when the child began to tell her own story, and (4) gazed back at Sam/child peer when the storytelling child was finished and was giving the toy and relinquishing the turn to Sam/child peer. In each case, the children in the singleton condition with Sam as a virtual peer showed a greater number of these indicators of turn-taking behaviors than children interacting with a child peer, ts(10) = 2.61, 2.66, 2.53, and 2.63, respectively, *p*s $<$ .01. In the child peer dyad condition, on the other hand, children rarely gazed at one another, and no significant differences in turn-taking behaviors were observed.

Reciprocal instruction (Palincsar & Brown, 1984) relies on taking turns and attending to the behavior of one's partner. It is possible, therefore, that successful literacy interventions incorporate enforced turn-taking of the sort that *Sam the CastleMate* demonstrates. This interpretation was supported by observations that Sam fostered collaborative behaviors between the two real children in the dyad condition. Stone and Christie's (1996) taxonomy of collaborative behaviors were used to assess the number of collaborative behaviors that were subsequently categorized into two types: story and non-story. Collaborative behaviors labeled as "story" were comments about the ongoing story (e.g., "pretend that she was eaten but she escapes"). Collaborative behaviors labeled as "nonstory" were about any topic except the ongoing story (e.g., "I have a toy like this").

The nature of the collaboration differed between the "dyad with Sam" and "dyad without Sam." The children in the "dyad with Sam" group engaged in more "story" collaborations than "nonstory" collaborations, *M*s (*SD*s) = 7.5 (4.23) and 2.0 (1.79), respectively, $t(5) = 3.18$, $p < .05$. That is, the children in dyads with Sam more often helped each other by commenting on one another's stories. The children in the "dyad without Sam" group engaged in more "non-story" collaborations than "story" collaborations *M*s (*SD*s) = 5.67 (1.97) and 1.00 (0.89), respectively, $t(5) = 12.79$, $p < .01$. That is, two peers playing without Sam's presence more often commented to each other on topics not related to the target task of storytelling. The children with Sam, then, talked more *about* storytelling than those without Sam. Sam engaged children more fully in collaboration related to storytelling, leading children to use decontextualized language, which in turn should prepare them for literacy.

In the research based on the six SLS included here, some striking relationships turned up between the use of the SLS and three crucial predictors of literacy. Children using SLS were shown to use more metalinguistic terms, more decontextualized language, and to engage in more prosocial collaboration with peers. This research did not target, however, the relationship between the use of SLS and actual school-based literacy evaluations, nor the effects of SLS on later literacy. To explore the effects of SLS on standardized language test performance and to examine use of SLS by children engaging in a broader spectrum of school-based language behaviors, we have begun to study how Sam functions in a classroom context, and the effect of interacting with Sam over several weeks. We are examining pretest and posttest scores on the Test of Early Language Development, 3rd edition (TELD-3)—a standard school-based receptive and expressive language test (Hresko, Reid, & Hammill, 1991)—for a sample of 31 five- to six-year-old children who interacted with Sam for an average of 4 times over 3 weeks. A paired sample *t* test analysis indicated that average posttest scores were significantly higher than the pretest scores for the receptive language subtest [*M*s (*SD*s) = 111.81 (9.20) and 107.39 (11.52); $p < .05$, respectively], the expressive language subtest [*M*s (*SD*s) = 103.10 (8.57) vs. 99.61 (9.93), respectively]; and the Spoken Language Quotient [(*M*s (*SD*s) = 108.90 (8.92) vs. 104.16 (10.84), respectively]. There is also a significant correlation between all three pairs of pre- and posttest language measures: $r(31) = 0.518$, $p < .005$; $r(31) = 0.374$, $p < .05$; $r(31) = 0.687$, $p < .001$), for receptive language, expressive language and spoken language scores, respectively. The amount of increase in the composite literacy score (Spoken Language Quotient) between the pre- and post-TELD tests was on the order of 5%, after an average of four sessions of 30 minutes with Sam, indicating that interaction with Sam is predictive of increased performance of exactly the sort schools hope when they use the TELD to measure literacy skills in young children.

Note that in this first school-based study there was no control group, that is, all children may increase from pre- to posttest by virtue of practice on the test, experience in school, maturation or many other factors; nonetheless the promise of Sam merits further attention given the confluence of findings that suggest this type of virtual peer facilitates these aspects of emergent literacy in a manner consistent with predictions based on theory.

Despite these positive and literacy-supporting aspects of children's collaboration with Sam, there were still serious limitations to the system, and many puzzles, which we are beginning to address. Sam engaged in no natural language understanding and thus did not really understand what the child was saying. And Sam was only able to exchange turns at the end of a story, and not as the story evolved. This led to occasional failures in communication as children began stories and expected Sam to continue them, or as children asked Sam explicit questions ("Sam, are you a girl or a boy" was a frequent question) and received no response. For this reason we have been investigating keyword spotting, natural language processing with commonsense reasoning, and nonverbal cues to floor management as a way of realizing a more real-time collaborative interaction between children and an embodied conversational agent (Wang & Cassell, 2003).

5. Implications and conclusions

The burgeoning field of emergent literacy has acknowledged the role of peers, of play, and of narrative in later academic competence, demonstrating a clear link between the features of emergent literacy described here—reported speech, temporal and spatial expressions, symbolicization of actual objects into fantasy objects—with the features of actual written literacy. When technologies have been designed to support literacy, however, these findings have not been incorporated. The work presented here demonstrates that, first of all, these features can be incorporated into technology, and second, when they are incorporated, that children perform well on tasks that are good predictors of later literacy and even on tests of early literacy.

The kinds of learning environments enabled by SLS provide opportunities for children to bridge informal and formal contexts by sanctioning and encouraging modes of play as avenues for the development of "school" language. But as well as informing the design of contemporary learning environments, the research reported here also impacts the fields of language acquisition, cognitive development, and early education. In fact, a recent study has shown that children's ability to take multiple perspectives in storytelling is positively correlated with their mathematical skills (O'Neill & Pearce, 2001), suggesting that development in metalinguistic awareness may have an effect beyond writing literacy. Intelligent Tutoring Systems might also profit from integrating models of peer relations of the kinds described here. Tutoring systems that could engage in fluid negotiation of roles—sometimes the more capable partner, sometimes needing some coaching or scaffolding of its own—would undoubtedly be engaging to children, but might also lead to strong learning results.

More generally, the systems described here demonstrate a model of collaboration between human and technology that is quite different than that found in most educational technology. SLS exhibit a kind of collaboration that resembles that found among peers more than the collaboration (or cooperation) between an expert and a novice. However, unlike the cognitive dimensions of peer learning companion systems, SLS demonstrate the importance of the social context of peer collaboration, its playful, spontaneous, personally meaningful dimensions, and its ability to evoke a desire to make oneself understood. All of these dimensions enter into the sociocultural understanding of learning, whereby the very fact of monitoring mutual understanding, of watching for how another understands what one has just said, changes one's understanding of one's own words or actions.

The four key principles that guide SLS allow them to be socio-culturally situated in this way. They (a) evoke playful language use and storytelling from children, and use children's propensity to tell stories to bootstrap literacy, (b) encourage peer play, and sometimes embody peers as playmates in the system, (c) do not require children to learn desktop screen–keyboard–mouse interfaces or to sit at a desk; instead the systems are built into children's toys, and thus invite the kind of embodied play that young children engage in, and (d) ask children to construct their own personally meaningful content rather than constraining the kind of stories that children can tell or listen to. These features are motivational in their own right but, more importantly, they help children to succeed at three crucial predictors of literacy: (i) using decontextualized language to make themselves understood, (ii) gaining metalinguistic awareness to be able to monitor the knowledge and understanding of audiences, (iii) collaborating with peers to make meaning for others that relies on meaning shared by others. For literacy learning, this process of appropriation (Rogoff, 1991) is key. Literacy, after all, is about participating in a community of meaning-makers.

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