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Smarty Ants®

RESEARCH TO PRACTICE **WHITE PAPER**

Developing and Sustaining Foundational Literacy with Smarty Ants®

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Smarty Ants: A Solution for Foundational Literacy Success

Despite historical and drawn-out debates on the best way to teach children how to read English, very little debate exists about the specific skills children need to develop in order to be successful readers today (Snow & Juel, 2005). In the landmark National Research Council publication, Preventing Reading Difficulties in Young Children, the Council emphasized that phonics activities and language activities that engage students with literary texts need to be integrated in order to reach all students (Snow, Burns, & Griffin, 1998; National Institute of Child Health and Human Development [NICHD], 2000). The findings were supported by the National Reading Panel (NICHD, 2000).

Yet the context for the integration of comprehension and phonics activities into the literacy classroom has shifted – and continues to shift – as we move into an information-centered economy where the literacy demands placed on children have been rising. These demands, such as the ability to think critically while reading, become more complex as children move on to high school and into careers. Consequently, many young students are struggling to reach these new goals established by the National Research Council and National Reading Panel (Kamil, 2003; Snow & Biancarosa, 2003; Snow, Griffin, & Burns, 2005). Estimates from the National Assessment of Educational Progress (NAEP) place only one third of fourth graders in the United States at or above the proficient level, leaving two thirds below proficient in reading tasks (National Center for Educational Statistics [NCES], 2011). This same level of proficiency holds true for eighth graders (NCES, 2011), begging the questions: What more can be done to address the other two thirds who struggle with reading? And how can their deficits be addressed through early intervention?

While many solutions have been proposed to address the performance gap, the most effective approach has been to focus on early intervention for all readers to bolster students' knowledge of five fundamental components of reading: phonemic awareness, phonics, vocabulary, fluency, and reading comprehension (McCain & Mustard, 1999; Snow, et al., 1998). Further, it is encouraged that interventions continue as needed for children (Snow & Biancarosa, 2003). As a result of these recommendations from researchers, increased efforts to address children's literacy needs produced a proliferation of reading-based software programs. However, many problems remained with how to determine the effectiveness of these software programs (Sandholtz, Ringstaff, & Dwyer, 1997; Schofield, 1995). More recently, a variety of ways have been proposed to evaluate such programs, including Bishop and Santoro's (2006) nine-point framework for beginning reading software that incorporates research from early reading education and instructional technology. The added dimensions of motivation and aesthetics afforded by scrutinizing the computer interface and instructional design, in addition to beginning reading content, provides a compelling, cross-disciplinary framework.

By blending elements from the National Research Council (Snow, et al., 1998), the National Reading Panel (NICHD, 2000), and Bishop and Santoro's frameworks (2006), this white paper presents how Smarty Ants incorporates a range of research-based activities, practices, and games into an interactive reading program. In addition, an explanation of how Smarty Ants may serve special populations, such as English language learners and special education students, is offered.

Smarty Ants targets the needs of all struggling readers. Its research-based curriculum and pedagogy were created under the advisement of a core team of educators from Stanford University and the University of California, Berkeley:

- ***Dr. P. David Pearson,*** *world-renowned reading researcher, professor, and dean emeritus of the University of California, Berkeley, Graduate School of Education*

- ***Dr. Robert Calfee,*** *distinguished professor emeritus of the Stanford University School of Education, and dean emeritus of the University of California, Riverside, Graduate School of Education*

- ***Dr. Mia Callahan,*** *graduate of Stanford University and the University of California, Berkeley, and seasoned reading teacher of 30+ years*

When designing the Smarty Ants program, the developers relied upon the findings of landmark intervention studies (e.g., Foorman, Francis, Fletcher, Schatschneider, & Mehta, 1998; Vellutino et al., 1996; Vellutino, Scanlon, & Jaccard, 2003; Torgesen, et al., 1999) and the most influential reading studies of the past 50 years (e.g., Bond & Dykstra, 1967; Chall, 1967; Anderson, Hiebert, Scott, & Wilkinson, 1995; Adams, 1990; Snow et al., 1998; NICHD, 2000). Whether Smarty Ants is used with typically developing readers or at-risk readers, it provides a curriculum and pedagogy consistent with what top researchers have discovered about how children learn to read.

The end goal of all reading instruction is reading comprehension – the ability to make meaning from print. Without it, early readers do not understand what they read, fail to read to learn, and ultimately struggle with literacy in their daily lives as adults. In order to understand the role that reading comprehension plays in later success, researchers have sought ways to model the reading process to understand where possible deficits or combinations of deficits in all stages of reading may inhibit further development.

Developmental Models of Reading

After extensive reviews of the extant research literature on reading, members of the National Research Council in their report, Preventing Reading Difficulties in Young Children (Snow, Burns, & Griffin, 1998), highlighted the specific points where the development of reading skills commonly break down, leading to difficulty comprehending text.

By relying on high levels of scrutiny and empirical evidence, the report narrowed a broad range of reading-related concerns into five categories: phonemic awareness, phonics, fluency, vocabulary, and reading comprehension. Building on the conclusions of the National Research Council, the National Reading Panel (NRP) report was published by the NICHD (NRP, 2000). Both the National Research Council and the National Reading Panel reports made it clear that a comprehensive approach to reading instruction is necessary if all children are to become efficient and effective readers. The essential components include explicit, systematic instruction in phonemic awareness (a sub-category of phonological awareness), phonics, fluency, vocabulary development, and comprehension strategies. Throughout the subsections below, this literature review refers to this model of reading to explain how developers at Smarty Ants have incorporated relevant strategies documented by scientific research into their software program.

Reading, however, is not purely a cognitive function; it occurs along developmental and social lines. Developmental psychologists have highlighted other factors that affect a child's success at reading tasks, including difficulty of the task itself and motivation. Perhaps the most famous schema for understanding how a child's development relates to his or her ability to complete tasks is the "zone of proximal development," a term coined by Lev Vygotsky (1978) to describe the zone where a child is optimally challenged to grow and learn with proper scaffolding. Thus, the zone of proximal development is the space where a challenging developmental task is also potentially instructive.

From the outset, Smarty Ants addresses the individual child's zone of proximal development by assessing what the child knows through an interactive assessment. Moreover, computer-adaptive lessons are found throughout Smarty Ants, in which instruction and activities change based on the success of the student at playing games and answering questions. All of the lessons and games have consistent feedback throughout that encourages the child at his or her demonstrated level, based on current and prior successes with the program. It is evident that Smarty Ants meets or exceeds the criteria for instructional technology programs referenced in Table 1.1 (Bishop and Santoro's framework, 2006) for instructional technology programs targeting early reading skills. Multiple opportunities to view progress are provided in all games, as well as in the reward room, the ant home, and the ant store.

Building Basic Skills

High-quality, technology-based interventions may help remedy early gaps in developing phonological awareness (Snow et al., 1998). Phonological awareness is the umbrella term, which primarily incorporates phonemic awareness and syllabification. For many students, excepting those with reading difficulties, phonological awareness comes from routine interaction with family members (Werker & Lalonde, 1988). Deficits in phonemic awareness are much more common, however. Phonemic awareness at its simplest is the ability to manipulate individual sounds in words. Phonics, on the other hand, is the teaching of how sounds relate to word spellings in systematic ways. Each of these will be further explained below with appropriate examples from the software.

Recognizing Letters and Letter Sounds

Critical reviews of reading research, such as the one conducted by MacArthur, Ferretti, Okolo, and Cavalier (2001), highlight how technology can potentially teach phonological awareness and decoding skills, especially now that many software programs teach letter-sound correspondences and allow for the manipulation of sounds in words. This is of critical importance, considering that one of the main stumbling blocks that children experience in developing their reading abilities is based on the simple concept that words are composed of both immutable and malleable components that, depending on their arrangements, create new words. Lessons 3-69 in Smarty Ants have children watching and participating in the creation of words from sounds. This occurs concurrently with the teaching of sound-letter correspondences.

Figure 1 – *The Assessment Pool is where each child is initially assessed for placement in the appropriately leveled learning environment.*

Table 1.1 – An evaluation of Smarty Ants using Bishop and Santoro's Framework for Instructional Support and Assessment (2006)

Criterion	Inclusion in Smarty Ants
Instructionally Supportive:	
• The program provides content support when the learner needs it	**• Yes**
• The content support is helpful but not so prescriptive it short-circuits learning	**• Yes**
• The program uses informative and instantaneous feedback messages to support content learning	**• Yes**
• The program branches automatically to accommodate the learner's remediation needs	**• Yes**
Assessing:	
• The program saves learners' work	**• Yes, continuously**
• The program provides progress summaries	**• Yes**
• The program graphs or charts learner performance in an easily interpreted way	**• Yes**
• The program interprets learner performance and makes recommendations for how to proceed	**• Yes**
• The program includes an administrative function that tracks all learners working with the program	**• Yes**

Smarty Ants directly teaches letter-sound correspondences through a variety of activities, including Four Square, Hoops, Treadmill, and other games. When children enter a lesson, they watch a brief teaching video from the Ant Coach. Children then have the option of playing a game like Treadmill, which as the name suggests, is based on the eponymous piece of gym equipment.

On the Treadmill, emerging readers are asked to listen to letters called out to them, and then jump on those letters as they move along the conveyor belt. When a letter has been accurately identified a specific number of times, the player wins that letter and is directed to incorporate that letter into words that are later used to build a story.

If the child gets the letter wrong, he or she is provided assistance and instruction. The transition is seamless in the games, as children then interact with the learning cloud videos that teach the sounds of the letters, often involving the inflating of letter-shaped balloons.

Figure 2 – *An ant on the Treadmill learning letter-sound associations.*

Activities that accurately represent letter sounds, provide feedback for the child during the learning process, and include prolonged engagement with the tasks, should produce results for children who are just building their letter-sound correspondence knowledge and mimic proven instructional tasks used in early childhood education (Cunningham, 2005). All of the activities in Smarty Ants provide this type of instruction.

Phonemic Awareness and Phonics

Identifying letters and their sounds are part of the picture of developing robust phonological awareness, but isolating the individual sounds in particular words is even more important. Referred to as phonemic awareness, the ability to isolate individual sounds represents the "metalinguistic understanding that spoken words can be decomposed into phonological primitives, which in turn can be represented by alphabetic characters" (Pugh, Sandak, Frost, Moore, & Mencl, 2006, p. 65). Phonemic awareness is learned primarily in a classroom environment (Snow, Burns, & Griffin, 1998). Typically, the sounds of letters, as well as letter combinations such as digraphs, diphthongs, and blends, also are taught in school in the form of phonics instruction.

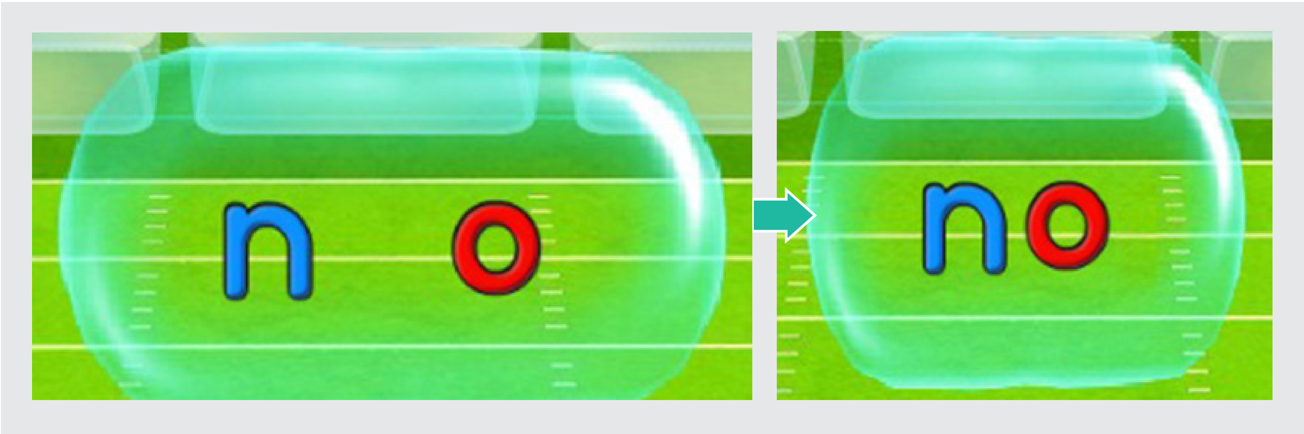

Figure 3 – ***Word bubbles illustrating blending phonemes to create words.***

In a Smarty Ants game such as Four Square, the child playing the game will be given the opportunity to identify letters. Then the letters' relationship to a word, illustrated on the screen above, will be shown with each phoneme blended both aurally and visually. Through the use of sound and word bubbles, the child is able to "see" the sequential blending of individual sounds merge together to form a word, while simultaneously hearing the sounds as they are blended.

This technique corresponds to a popular instructional strategy called sound boxes. Sound boxes, like many other strategies used to isolate and manipulate phonemes in words, emphasize the individual phonemes as well as the process of blending phonemes. Preliminary research has shown that the systematic use of sound boxes or phonemic segmentation has positive effects on developing phonemic awareness (McCarthy, 2008; Yeh & Connell, 2008).

Another way that phonemic awareness is explicitly taught in Smarty Ants is through the use of rhymes. Because traditional rhyming games require an understanding of how to manipulate sounds in words, they can be effective in teaching simple manipulation of phonemes. Research suggests that, due to the complex nature of developing a tiered curriculum in many classrooms on phonemic awareness (McGee & Ukrainetz, 2009), computer-based programs may be one of the best ways of developing mastery in this area. Table 1.2 presents the aspects of alphabetic understanding and phonological awareness that are found in Smarty Ants.

Phonological awareness is taught in combination with alphabetic understanding in Smarty Ants. While the Bishop and Santoro (2006) framework suggests that it is best to learn phonemic awareness without letter representations, the National Reading Panel Report (NICHD, 2000, p. 7) states that phonemic awareness instruction "is most effective when children are taught to manipulate phonemes by using letters of the alphabet." Furthermore, initial observations of children playing Smarty Ants suggest that children spontaneously speak the sounds and words taught within the program. So while two components of Bishop and Santoro's (2006) framework are not addressed exactly as articulated, deeper observations reveal that flaws may exist with the framework as designed.

Table 1.2 – An evaluation of Smarty Ants using Bishop and Santoro's Framework for Alphabetic Understanding and Phonological Awareness (2006)

Criterion	Inclusion in Smarty Ants
Alphabetic Understanding:	
• The program uses concrete representations for manipulating letters in the word	**• Yes, with word bubbles**
• The program requires learners to manipulate the letter-sound correspon-dences in words	**• Yes, in Rhyme Time & Word Building in each lesson**
• The program develops learners' skills at producing letter-sound correspon-dences in words	**• Yes, in Learning Clouds, Word Building, and Story Building**
Phonological Awareness:	
• The program only uses concrete representations, not text for manipulating speech units	**• Both are included**
• The program requires learners to manipulate targeted speech units auditorially	**• Yes**
• The program develops learners' skill at producing targeted speech units	**• Not explicitly. Smarty Ants pilot research reveals that children spontaneously orally repeat the speech units they see and hear the Ant Coach presenting in the learning clouds.**

Reading Words and Phrases

Learning letter shapes, names, and sounds and becoming phonemically aware are all crucial to a child's ability to grasp the alphabetic principle that units of print map onto units of sound (Perfetti, 1984). For some children, this principle may be induced, but for most the concept is learned in school through explicit, systematic phonics instruction. The importance of grasping the alphabetic principle cannot be overemphasized: "Children must be able to independently decode the many unknown words and phrases that will be encountered in the early stages of reading. By acquiring some knowledge of spelling-to-sound mappings, the child will gain the reading independence that eventually leads to the levels of practice that are prerequisites to fluent reading" (Stanovich, 2000, p. 162).

It is important to acknowledge, as well, that alphabet knowledge, phonemic awareness, and the understanding and use of the alphabetic principle all need to be in place early in the child's development (Biemiller, 1977-78; see also Allington, 1980, 1983, 1984). Large differences in reading practice can begin to emerge, resulting in poorer readers being exposed to less text than their peers. Using the Smarty Ants computer program, the child's learning of letter-sound correspondences, phonics, and phonemic awareness is reinforced and automatized. Upon a strong foundation of early reading skills, the children using the program can develop emergent components of fluency, vocabulary, and reading comprehension, which will help them complete increasingly complex reading tasks.

Fluency

Reading fluency has become an important predictor of reading comprehension skills in all learners (Kuhn & Stahl, 2000; Rasinski & Hoffman, 2003). Fluency is composed of three components: automaticity (automatic decoding), prosody (voice and intonation), and pacing. Essentially, a fluent reader is able to read text at his or her level with the speed, emotion, and intonation that results in optimal comprehension. Fluency becomes an important component of moving children past the stage where the identification of words, one-by-one, consumes so much reader attention. Upon becoming more fluent, children can devote more cognitive resources to reading comprehension (Chard, Vaughn, & Tyler, 2002; LaBerge & Samuels, 1974; Posner & Snyder, 1975; Stanovich, 1980; Rasinski, 1989).

The use of chunking of phrases in the simple stories in the story-building module of each lesson moves students from word calling to reading with a natural pace and rhythm. Children are initially asked to select words that become part of a sentence in the story. As the child's ability to select words increases, so too, does the length of the phrase that he or she selects. In order to keep pace with the game, the child is slowly eased into reading and recognizing longer phrases and sentences, following the fluency coach model described by the research team of fluency expert Dr. Tim Rasinski from Kent State University (Rasinski, Homan, & Biggs, 2009).

Vocabulary

The explicit teaching of vocabulary cannot happen early enough for students. Important studies such as those conducted by Hart and Risley (1995) clearly outline how early deficits in word knowledge become compounded over time, leaving children far behind their higher-achieving peers. Part of developing a robust vocabulary includes learning the most common words early on while also learning uncommon or academic words (Beck, McKeown, & Kucan, 2002).
Smarty Ants teaches word recognition initially through phonemic awareness activities, and later moves into learning words through word games incorporating sound/symbol correspondences (phonics), and practice reading the words in longer stories. Table 1.3 illustrates the degree to which early reading skills are incorporated into the program.

As students master the words by identifying them correctly at least three times in the games, they accumulate the words in the reward room. Here students can see which words they have mastered, as well as ones they are still working on. When the words are clicked on, they are segmented and pronounced using the word bubbles. This dynamic word-wall style presentation corresponds to well-known practices for enriching vocabulary instruction, because it often organizes the words into families, morphological categories, and/or phonetic categories depending on the level of the student (Beck & McKeown, 2007).

Reading Comprehension

Developing a deep understanding of what is read comes about through a complex set of cognitive processes, and through fluency with a variety of reading-related cognitive tasks. Early on, however, teaching reading comprehension stresses recall, sequencing, predicting and summarizing as requisite skills of reading comprehension (Snow, Burns, & Griffin, 1998).

In Smarty Ants, the Story Game Show, which is accessible after completing a variety of games on the activity board, is the main site of reading comprehension activities. A variety of questions asked in a game show format allow the child to demonstrate mastery of a library of stories. Metacognitive thinking strategies are modeled throughout, both by the host of the show and the ant friends that the child invites to play along and react to the story (Harvey & Goudvis, 2007).

Figure 4 – *In Story Game Show, questions about the stories provide clues to early reading comprehension skills.*

Table 1.3 – An evaluation of Smarty Ants using Bishop and Santoro's Framework for Reading (2006)

Criterion	Inclusion in Smarty Ants
Word Reading:	
• The program introduces new words in isolation as opposed to within the context of a story	**• Yes**
• Reading passaged and/or words are presented at the learner's skill level	**• Yes, lessons are scaffolded and adaptive to the individual's needs**
• Words presented are embedded across multiple texts and/or activities	**• Yes, through multiple activities, and in both phonics stories and authentic literature in the Story Quiz Game Show**

Reading Words and Phrases

Critical to any high-quality reading program are its motivational components because, without them, children become disengaged. Our understanding of reading motivation, and the nature of motivation in general, has improved in recent years (Eccles, 1983, 2009; Ford, 1995; Ford & Smith, 2007; Ryan & Deci, 1985, 2000). Across these different models for understanding motivation, a few theoretical constructs remain fairly consistent.

For example, self-determination theory (Ryan & Deci, 1985, 2000), with its component structure of autonomy, competence, and relatedness, presents a fruitful approach to understanding the individual profile of young readers. In this model, autonomy refers to the degree to which individuals perceive an ability to determine their relationship to a task; competence stresses perceptions of their ability to do the task itself; and relatedness reveals the degree to which they feel connected to the task. Additionally, from the perspective of research on motivation and reading more specifically, Guthrie and Wigfield (2000) highlight how technology serves as a strong motivator for struggling readers.

Technology-based reading programs, which offer choice and stress mastery for early readers, may also help develop the skills that students need (Bishop & Santoro, 2006; Barker & Torgesen, 1995; Torgesen & Barker, 1995). Throughout the Smarty Ants program, students develop competence through the completion of leveled and scaffolded tasks and lessons. Students develop autonomy through the choices they have in activities and in selecting what they would like to master first. Additionally, relatedness is developed through the interaction between each student's virtual ant friends, parent letters found in the Teacher's Guide, and the Daily Woof newsletter, which touts the child's accomplishments to selected family and friends via e-mail.

Evaluating Aesthetics and Operational Elements of Smarty Ants

One of the pervasive problems with instructional software – especially software that targets reading skills – is that it is often aesthetically confusing and does not present an intuitive interface. Bishop and Santoro's (2006) framework for evaluating technology-based interventions for reading includes aesthetic and operational elements. Presented in Table 1.4, these elements have been carefully considered by the designers of Smarty Ants.

Language Learners

In general, most struggling readers fall into two broad groups (Torgesen, 2004). The first group includes children who, despite adequate oral language development, have an underlying deficit in phonological processing. They are, by nature, less sensitive to the sounds in language and have difficulty understanding the alphabetic principle – the fact that symbols in print can represent those sounds. Consequently, remembering letter-sound associations, mapping sounds to symbols to read words, and creating mental representations of words for automatic and fluent reading is a tremendous challenge for these children. This cluster of symptoms, that is sometimes referred to as dyslexia, affects between five to 17 percent of the United States population, depending on the threshold used to define the impairment (Shaywitz, 2003). Dyslexia also results in slow and inaccurate reading, poor spelling, difficulty with written expression, and, consequently, challenges in all academic endeavors. Current research has provided clear evidence that dyslexia is not due to a lack of intelligence or desire to learn, but rather to differences in brain organization and function (Dehaene, 2009). It occurs in people of all backgrounds and intellectual levels, often runs in families, and exists on a continuum from mild to severe (Dehaene, 2009).

Children in the second group display weaknesses in both oral language development and the phonological skills necessary for skilled reading. These may be English language learners, children with developmental delays in language, or economically and educationally disadvantaged children with fewer opportunities for rich language development. Because environmental conditions that affect oral language development also impact the growth of phonemic awareness, print awareness, and letter knowledge (McArdle & Chhabra, 2004), these children are doubly affected when it comes to learning to read.

Table 1.4 – An evaluation of Smarty Ants using Bishop and Santoro's Framework for Aesthetics and Operational Components (2006)

Criterion	Inclusion in Smarty Ants
Aesthetics:	
• The media used is high quality	**• Yes, original art and 3D graphics are used**
• Screens are laid out in well-organized ways	**• Yes, navigation is intuitive for children as young as three years old**
• Screens are neither over-stimulating nor boring	**•Yes, white space is included around the game inter-face, and limited graphics appear on each screen to enhance instruction**
• The "look and feel" of the program is likely to be pleasing to the learner	**• Yes, bright colors and graphics are used**
• Media are used to create themes/metaphors that relate to content and help create meaning	**• Yes, ant characters are used in all phonics stories, and images provide a visual definition of words**
• Learner is able to modify the interface according to individual preferences	**Yes, screen and audio settings can be adjusted; Children can purchase clothes and accessories for their avatar, virtual dog and friends to change their appearance**
Operational Supports:	
• All operational instructions are supplied auditorially within the program	**• Yes, with visual demonstrations from the Flea character**
• Operational instructions can be reviewed as necessary	**• Yes**
• Things on the screen appear to function the way the user might expect	**• Yes**
• The interface responds with prompt and informative invalid action messages when appropriate	**• Yes**
• After repeated invalid actions, the interface shows the learner how to correctly operate the function	**• Yes**
• The interface takes advantage of what learners already know	**• Yes, children can skip instructions if they already know how to play**
• Program functions are placed in equivalent, if not iden-tical, locations on screens	**• Yes**
• Things on the screen appear to function the way the user might expect	**• Yes, the program is fully intuitive with no variation in navigational tools**

Smarty Ants shows promise in both populations for similar reasons. The instruction provided is explicit, scaffolded, and matched to the student's demonstrated needs. The designers of Smarty Ants have made a few assumptions about the required requisite skills of children who use the program: mainly, that they must be able to hear the voices of the characters and be capable of using a mouse. Sound-letter correspondences, phonemic awareness, reading fluency, vocabulary, and reading comprehension are not taught in such a way that excludes children who are English language learners or who have a reading disability. A main difference is that certain sections like sound-letter correspondences and phonemic segmentation may take more time for these children to complete successfully – though the nonjudgmental and private nature of the software program itself offers a more sensitive treatment of these often stigmatized populations. Moreover, portions of the program have been translated into Spanish so that Spanish-speaking children can hear directions in their native language if dual-language instruction is desired. For these children, the program also includes an additional vocabulary pre-teaching module in every lesson, so that children will more effectively learn new vocabulary in the context of their native language and English.

Figure 5 – *Children play an English vocabulary game at the beginning of each of the 67 story lessons in the dual-language version of Smarty Ants.*

Conclusion

While formal experimental studies of the effectiveness of Smarty Ants are currently underway, initial interaction in the immersive environment makes plain the purposeful and research-based design that affects each lesson and each component of early reading success (Snow et al., 1998; NICHD, 2000). In addition, of the components that Bishop and Santoro (2006) outline in their framework for early literacy computer programs, all of the research-based components are present and usually in more than one situation. Based on strong scientific evidence, Smarty Ants is one pathway to developing the skills of early readers, both generally and specifically.

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