Technology Infusion in Success for All:

Reading Outcomes for First-Graders

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Abstract

This article evaluates two applications of technology to the teaching of beginning reading. One, embedded multimedia, involves brief video content threaded through teachers' lessons, focusing on phonics and vocabulary. The other, computer-assisted tutoring, helps tutors with planning, instruction, and assessment. A randomized experiment in Success for All schools compared students randomly assigned to technology or non-technology conditions in a year-long study. Tutored first graders who received both technology enhancements scored significantly higher on four reading measures than students tutored without technology (median ES= +0.53). Non-tutored students who experienced just the embedded multimedia scored significantly higher than non-tutored students taught without technology on two reading measures (median ES= +0.27) The results suggest that the use of technology to enhance rather than replace teacher instruction may have important benefits for children.

Technology Infusion in Success for All: Reading Outcomes for First-Graders

For more than half a century, a technology revolution in education has been just around the corner, yet it never quite arrives. In the 1950's and '60's the revolution was to be led by television and film, and since the 1970s, it was to be computers. In fact, televisions and computers are now commonplace in education at all levels (see, for example, U.S. Department of Education, 2002). Yet the revolution remains elusive. Video is still a rainy day activity, poorly integrated with instruction. While computers are widely used for word processing, other frequent applications are separate from core instruction: skill practice games, remediation, and reference software (Becker, 2001). Technology has certainly not transformed teaching or learning (Becker & Ravitz, 2001; President's Panel on Educational Technology, 1997).

Technology plays a particularly limited role in the teaching of beginning reading, although several studies have found promising possibilities. Evaluations of the effects on language and literacy of well-developed education television such as *Sesame Street* (Ball & Bogatz, 1971; Fisch & Truglio, 2002; Rice, Huston, Truglio, & Wright, 1990), and *Between the Lions* (Linebarger, Kosanic, Greenwood, & Doku, 2004) have shown positive outcomes for young children. A recent review by Kulik (2003) found that well-designed studies of uses of computers to teach reading produce mixed outcomes. However, there are several studies that have found positive effects of computer applications on such skills as phonological awareness (Foster, Erickson, Foster, Brinkman, & Torgeson, 1994; Wise, Ring, & Olson, 1999), letter and word recognition

(Mioduser, Tur-Kaspa, & Leitner, 2000), and other reading skills (Greenlee-Moore & Smith, 1996; Torgeson & Barker, 1995).

The present study reports an evaluation of two approaches that infuse technology into beginning reading instruction: embedded multimedia and computer-assisted tutoring. Both of these approaches fully integrate technology into teachers' instruction. The following sections present rationales for each of these applications.

Embedded Multimedia

Embedded multimedia (Chambers, Cheung, Madden, Slavin, & Gifford, in press) refers to the use of brief video[*] content that is woven into the teacher's lessons. Instead of substituting for the teacher, embedded multimedia supplements the teacher's instruction by providing compelling illustrations of concepts the teacher is teaching. The video material gives students linked pictures and words to help them remember the content, modeling proficient performance. Further, it models the content for teachers, giving them clear demonstrations of both content and teaching strategies.

The theoretical basis for embedded multimedia begins with Paivio's dual coding theory (Clark & Paivio, 1991), which demonstrated that information held both in verbal memory and in visual memory is retained better than information held in only one memory system. For example, Mayer (2001) and his colleagues carried out a series of experiments in which students were taught how lightning works. Teaching about lightning using narration alone or text alone teaches only to verbal memory. Adding diagrams or moving pictures to illustrate the concept teaches to visual memory. Adding

[*] Throughout this paper, the term "video" is used to refer to VHS, DVD, or CD formats.

the pictures to narration or text greatly increased initial learning of the concept, as well as both retention and transfer, as long as the pictures and text or narration were closely aligned with each other and focused on the instructional objective (Mayer & Moreno, 2003).

Another key concept in multimedia learning is cognitive load. It has long been known that working memory places a severe limitation on the amount of information that can be absorbed at any given time (Solso, 2001). Each learning objective has a given intrinsic cognitive load, and if this exceeds the working memory capacity of children of a given age or level of knowledge, the objective must be broken into components that "fit" within the child's working memory capacity (Paas, Renkl, & Sweller, 2003). However, each memory system has its own limitations, which may be fairly independent of one another. That is, a learner has a limited working memory capacity for words and a limit for pictures, but "using up" the word limit does not "use up" the picture limit. Therefore, Mayer and Moreno (2003) suggest that instructors or designers can "off-load" meaningful information from one channel to the other, by using fewer words and more pictures when verbal working memory would otherwise be overloaded. Again, this "off-loading" only works if the pictures and words directly support each other. Pictures that are interesting but irrelevant to the words, containing "seductive details," can be detrimental because they fill limited working memory with the irrelevant content (Mayer, 2001).

The complementary nature of words and moving pictures has been demonstrated in a series of studies in which instructional video material was broken into audio and silent video components and compared to the full video with audio (see Kozma, 1991, for a review). In most cases children learned significantly more from the video-audio presentations. This supports the concept that narrative and picture information do not interfere with each other, but instead support each other.

Embedded multimedia takes advantage of these theoretical principles, combining verbal and visual content (words and moving pictures) to give learners multiple pathways to retention and comprehension and interspersing “bite-sized segments” with opportunities to practice and apply new learnings. For example, a key problem in early reading instruction is teaching associations between letter shapes and letter sounds. The embedded multimedia strategy described in this article contains a series of animations designed to link the letter shape and letter sound in a brief, memorable story. In introducing the /p/ sound, for instance, a parrot eats some watermelon, and then spits out the seeds, making the sound /p/, /p/, /p/. The seeds fall in the shape of the letter “p”. This 30-second story, which young children readily learn and remember, gives them a link in their visual memory between the shape “p” and the sound /p/ that they can easily access, adding to the verbal and tactile learning the teacher provides by having children look at a picture of the parrot in the shape of the letter “p” and having them make the /p/ sound and noticing how their mouths move when they do so.

It is important to note that multimedia is not assumed to be beneficial in itself. Passively watching videos might support children’s reading but it does not teach children to read. Children need to apply and discuss their new learnings from the multimedia. For example, in English reading, children must learn 44 phonemes represented by more than

60 graphemes (Adams, 1990). In order to quickly and automatically recognize each, and avoid confusions among them, children need to practice them separately and in words and sentences. Additional instruction and practice is necessary to solidify learnings from multimedia content. This is why we hypothesize that brief multimedia segments embedded in well-designed instruction, practice, and assessment will be more effective than multimedia content alone.

Similar theories underlie other multimedia applications in beginning reading (see Pailliotet & Mosenthal, 2000). To teach sound blending, the present experiment used video skits showing puppets sounding out words, creating both visual and auditory representations in memory. These brief segments were followed up with cooperative practice with words and connected text. To teach the vocabulary of the stories the students will be reading, live-action skits acted out the meanings of key words, both in context and then out of context. Again, students were expected to recall the skits (in their visual memories) to gain access to word meanings (needed in their verbal memories). They then practiced these words in their cooperative groups in meaningful contexts, to solidify their understandings.

Success for All and Embedded Multimedia

In 2001, researchers and developers at the nonprofit Success for All Foundation and Johns Hopkins University began a project to enhance the Success for All reading program with embedded multimedia. Success for All teaches beginning reading using a systematic phonics approach (see Slavin & Madden, 2001, for a program description). Fifty experimental-control comparisons of one or more years' duration have found, on average, positive effects of Success for All on children's reading achievement (see Borman, Hewes, Overman, & Brown, 2003; Herman, 1999; Slavin & Madden, 2001). A national randomized evaluation involving 38 schools has again found significant positive impacts on reading performance (Borman, Slavin, Cheung, Chamberlain, Madden, & Chambers, in press).

The addition of embedded multimedia to Success for All's beginning reading program was intended to enhance the effectiveness of the program by giving children compelling, memorable demonstrations of letter sounds, sound blending strategies, vocabulary, and comprehension strategies. A particular focus was on the needs of English language learners, who were felt to be in particular need of visual models for vocabulary and sound blending.

A preliminary study of the embedded multimedia strategy was carried out by Chambers, Slavin, Madden, Cheung, and Gifford (2005a). In that study, four schools primarily serving Hispanic students were compared with four matched schools with similar demographics and achievement histories. The experimental schools used Success for All with embedded multimedia, while the control schools used traditional basal approaches. After a one-year implementation, students in the Success for All/Embedded Multimedia treatment scored significantly higher than those in the matched control group, controlling for Peabody Picture Vocabulary Test (PPVT) pretests, on the Woodcock Word Identification, Word Attack, and Passage Comprehension scales. There were no differences on Letter Identification.

The Chambers et al. (2005a) experiment established the combined effect of Success for All reading and embedded multimedia on reading achievement, but it did not allow for a test of the unique contribution of the embedded multimedia content. A second year-long study, by Chambers, Cheung, Madden, Slavin, & Gifford (in press), was designed to determine the unique contribution of the embedded multimedia. This study, involving 10 high-poverty, majority-Hispanic schools with 394 first-graders in Hartford, CT, randomly assigned schools already using Success for All to either add the use of the embedded multimedia or not to do so. Results at the school level using hierarchical linear modeling, controlling for PPVT and Woodcock Word Identification scores, indicated significantly positive effects on the Woodcock Word Attack scale (ES = +0.32) and nonsignificant positive effects on Woodcock Word Identification and Passage Comprehension scales and on DIBELS fluency.

Computer-Assisted Tutoring

One-to-one tutoring is the most effective form of instruction known (Wasik & Slavin, 1993). It gives students the undivided attention of a valued adult, and gives the tutor freedom to adapt instruction to the unique needs of each child. In high-quality tutoring, tutors respond to the individual child's needs, adjust their instruction so that it is within the tutee's zone of proximal development, and provide immediate feedback on progress (Torgeson, Wagner, & Rashotte, 1997; Wasik & Slavin, 1993).

The Success for All program calls for the provision of 20-minute daily one-to-one tutoring to children, especially first graders, who are struggling with foundational reading skills. Approximately one third of first graders typically receive tutoring. Originally, Success for All required certified teachers as tutors, but due to the unavailability of sufficient certified tutors, as well as their cost, most schools now use paraprofessionals to do tutoring.

The computer-assisted tutoring model, called “Alphie’s Alley” (Danis, Rainville, Therrien, Tucker, Abrami, & Chambers; 2005), was designed to help tutors make effective use of tutoring sessions to help at-risk children make adequate progress in reading. The program increases program fidelity by assisting tutors and students in each of the three phases of tutoring - planning, instruction, and assessment. It also aims to increase motivation and learning through the use of engaging multimedia for students and for tutors through just-in-time professional development. Making learning relevant, understandable, and engaging increases time-on-task, which is especially important for struggling readers.

Alphie’s Alley structures the entire 20-minute tutoring session. The computer guides the individual student’s assessment and suggests individually tailored tutoring plans based on that assessment. It provides students with multimedia screens containing 12 types of tasks designed to build skills such as phonemic awareness, sound blending, comprehension monitoring, and connected reading. The tutor has an active role in guiding the child, assessing his or her ongoing progress, and modifying plans in light of each child’s needs, so the computer serves as an aid, not a replacement for the tutor.

The computer also provides professional development for the tutor, including video clips showing expert tutors implementing each type of activity with children with various strengths and weaknesses. This “just-in-time” professional development is expected to help tutors to become more thoughtful and strategic in working with their at-risk students (Chambers, Abrami, McWhaw, & Therrien, 2001). It builds on models of cognitive apprenticeship (Collins, Brown, & Newman, 1989) and self-regulated learning (Randi & Corno, 2000).

Alphie's Alley contains a complex database that allows the computer to make "intelligent" decisions on interventions and strategies based on the individual performance of each student, both between and within sessions (Everson, 1995; Mitchell & Grogono, 1993). The computer analyzes the student's responses and provides to the tutor suggested templates of instruction for that individual student. The tutor can choose to have the student engage in the suggested activities or can choose other activities, based on his or her knowledge of the student's abilities. The computerized diagnostic and assessment activities simplify record-keeping so the tutor's full attention can be devoted to the student.

There are several key concepts that underlie the design of Alphie's Alley. One is the use of embedded multimedia, as described previously. Giving the students animated representations of concepts such as letter sounds, sound blending, and sequence of events in a story is expected to help children master reading skills. For example, the computer progressively moves letters closer to each other to represent sound blending, and it shows pictures from stories out of order for children to put in proper sequence. Second, the interaction of tutor and computer builds on the strengths of each. The computer organizes and presents attractive animations, keeps records, provides consistent feedback and scaffolding based on the student's performance and so on, but no machine can replace a tutor's skills in listening to children, giving them feedback on their oral reading, and most importantly, forming human relationships with them. Finally, the computer's professional development capacity is expected to help tutors build their own understandings of how to implement the program and, more importantly, how to reach a broad range of children with diverse learning strengths and difficulties.

Alphie's Alley includes scaffolding for students and tutors so that there is both support and flexibility built into the tool. The flexibility means experienced tutors can use the tool as their expertise suggests, while novice tutors can rely more on the scaffolding programmed into the software.

In developing Alphie's Alley, we used a combination of existing research, surveys, focus groups, consultations, observations, and annual testing for formative evaluation to create a tool that was theoretically sound, practically useful, and empirically supported. Initial reports from the pilot testing include a limited amount of quantitative data collected in a quasi-experimental design in year 3 of research and development. Students in regular Success for All tutoring were compared to students who participated in Success for All tutoring with Alphie's Alley. A significant multivariate effect size of .39 (N=27 tutees) was found in favor of those who were tutored using Alphie's Alley on Word Identification, Word Attack, and Passage Comprehension subtests of the Woodcock Reading Mastery Tests-Revised and DIBELS Oral Reading Fluency when pretest scores on the Peabody Picture Vocabulary Tests were used as a covariate.

Schmid, tucker, Jorgensen, Abrami, Lacroix, and Noclaidou (2005) examined tutor reactions to Alphie's Alley versus traditional "paper and pencil" forms of tutoring support within SFA, using pretest and posttest surveys. They concluded that Alphie's Alley assumed and maintained a central role throughout the year. Tutors consistently reported that students were highly motivated to come to tutoring and appeared to learn at a rapid pace.

The Alphie's Alley program was first summatively evaluated in a year-long randomized experiment in which first graders who were eligible for tutoring within 25 Success for All schools were assigned at random to receive ordinary one-to-one tutoring without technology or one-to-one tutoring with Alphie's Alley (Chambers, Abrami, Tucker, Slavin, Madden, Cheung, & Gifford, 2005). Because of the newness of the program and difficulties maintaining distinct treatments within the same schools, implementation fidelity varied considerably; thus, overall experimental-control differences were not statistically significant. However, analyses among the 49% of children whose tutors used the program consistently and properly showed positive effects in comparison to control children on the Woodcock Letter-Word Identification and Word Attack scales and on DIBELS Fluency. Directionally positive but nonsignificant differences were also seen on the Gray Oral Reading Test and Woodcock Passage Comprehension.

The Present Study

The present study was undertaken to evaluate the combined effects of the Reading Reels embedded multimedia content and the Alphie's Alley computer-assisted tutoring model. Because only tutored children receive Alphie's Alley, the study allowed for a test of Reading Reels alone among non-tutored children as well as a test of the combined programs among tutored children. The present study also used an experimental design in which children in multi-track year-round schools were randomly assigned to tracks, and then tracks were randomly assigned to conditions. This was expected to facilitate more distinct implementations of experimental and control conditions than was possible in the Chambers et al. (2005a) experiment, because tracks within multi-track year-round schools are essentially separate schools-within-schools.

Because the study used random assignment of students and teachers to treatments within the same schools, it eliminated selection bias as a possible confound. The study schools were experienced Success for All schools, so instruction, curriculum, grouping, and other factors were identical in all groups. The only factor differentiating experimental and control groups was use or non-use of the embedded multimedia treatment in reading classes and of computer-assisted tutoring in one-to-one tutoring sessions.

Method

Design

The study took place in two large, multi-track year-round schools that had been implementing Success for All for several years. In each school, each student was part of a "track" that followed a schedule of four sessions over the year with vacation time between sessions (i.e., time usually allocated to summer vacation was instead divided into four mini-vacations). Multi-track schools of this kind are not uncommon in growing areas of the West, and are primarily intended to utilize buildings all year, to reduce the need for school construction. For researchers, multi-track schools of this kind offer an opportunity to randomly assign students to one of four "mini-schools" (i.e., the tracks), in a situation in which an essentially random process is in use by the schools themselves, which generally want the tracks to be equivalent to each other in student characteristics.

On entry to first grade, children in the two schools were assigned at random to one of the four tracks. Then tracks were randomly assigned to treatments (technology or no technology). Teachers assigned to the no technology control group were given the technology and training at the end of the year-long study, so this was a delayed treatment control group comparison.

There were a few children who could not be randomly assigned to tracks because they had a sibling in a given track and their parents wanted both children in the same track so they could take family vacations together. These children were non-randomly assigned to their sibling’s track. A test for differences between these students and those who were randomly assigned found nearly identical scores, so these children were included in the analyses.

Participants

Subjects were 159 first graders in two multi-track, year-round schools. One was a charter school of 1487 students in Los Angeles, in which 94% of students received free lunch and 97% were Mexican-American. The other was an public elementary school of 756 students in Las Vegas, in which 81% of students received free lunch and 69% were Mexican-American, 17% were Caucasian, 7% were Asian-American, and 6% were African-American.

Experimental Treatments

In the experimental group, all students were instructed in reading using Success for All with embedded multimedia. Students who needed tutoring were provided one-to-one tutoring with a tutor using Alphie's Alley.

1. *Success for All with Embedded Multimedia*. The embedded multimedia content consisted of 30-second to three-minute skits and other demonstrations integrated into teachers' daily 90-minute Success for All reading lessons. No additional time was added to the lessons to accommodate the multimedia. The purpose of the multimedia content was to directly present to students compelling demonstrations of key elements of beginning reading: letter sounds, sound blending strategies, and vocabulary. In addition, it was hoped that by showing multimedia content in class, teachers would have constant reinforcement of effective teaching strategies.

The multimedia materials ultimately created for the program were called Reading Reels. Reading Reels includes the following components.

<u>*The Animated Alphabet*</u>. Animations teach and reinforce sound/symbol relationships. For example, the animation introducing the short /e/ sound features an elephant pushing a rock with an "e" on it up a hill, making an /e/ sound with each push. At the top, the rock rolls down, and the exhausted elephant says "ehhhh" in frustration. The pairing of the memorable images, the letter sound, and the letter shape gives students many mental pathways to link the letter with its sound. There are animations for 58 different graphemes that comprise most of the phonemes used in the English language. Key cards with pictorial representations of the phonemes are posted in the classroom and

used by the teacher to review letter-sound correspondences. Each animation is between 30 seconds and one minute long.

The Sound and the Furry. Multimedia skits, using SFA puppet characters, model the word blending process, phonemic awareness, spelling, fluency, reading strategies, and cooperative learning routines. For example, a puppet sees a sign, "Watch out for stick." He sounds out the word "stick" phonetically. Then he notices a stick, which he picks up. The stick sticks to his fur, and in trying to get it off he bites it—and then realizes he's in real trouble. After the skit, the sounding out section is repeated, and children sound out the word along with the puppets. More than a hundred and twenty such vignettes illustrate sound blending strategies from simple CVC words to multi-syllable words. The average puppet skit is about two minutes long.

Word Plays. Live action multimedia skits dramatize important vocabulary concepts from the Success for All beginning reading texts. These skits are particularly designed to help students build the specific vocabulary for the books they will be reading. For example, when children are about to read a story about China, they first see a skit that introduces words such as "chopsticks," "fireworks," "beautiful," and "ugly." The average Word Play is about three minutes long.

Between the Lions. Puppet skits and animations from the award-winning PBS program help teach phonemic awareness, sound/symbol correspondence, and sound blending. Between the Lions segments are about one minute long.

The embedded multimedia materials were developed to be particularly beneficial to English language learners. In particular, the vocabulary skits demonstrating the vocabulary emphasized in each story that children are about to read were designed to ensure that all children know the vocabulary in advance so that they can focus on the decoding and comprehension tasks required to master and enjoy each book. The alphabet and sound-blending segments are also designed to build children's language skills as well as their reading skills.

Reading Reels at Home. Video or DVD versions of the Reading Reels including the Animated Alphabet, The Sound and The Furry, and Word Plays (but not Between the Lions content) were sent home with children in the experimental treatment. Parents were asked to encourage children to watch Reading Reels at home.

2. *Computer Assisted Tutoring.* Students who experience difficulties in reading in Success for All are assigned to daily 20-minute one-to-one tutoring sessions. In the experimental group, tutors used Alphie's Alley, the computer-assisted tutoring program specifically designed to align with the SFA curriculum. The program has four components: assessment, planning, computer activities, and just-in-time professional development.

Assessment. Alphie's Alley assesses children's reading strengths and difficulties in the areas of phonemic awareness, phonics, fluency, and comprehension. It communicates this information on an assessment report for each student. The program continuously updates information relevant to the student's progress.

Planning. The program suggests a two-week tutoring plan based on the child's assessment. The tutor may modify the plan in light of the child's performance and needs. From the tutoring plan, the student and tutor choose a goal for the student to focus on each week. At the end of the two-week period, a new plan is generated based on the student's performance on the activities.

Computer Activities. Alphie's Alley is a computer-based learning environment built around Alphie the Alligator and his friends. Students work on Alphie's Alley computer activities specifically designed to reinforce skills taught in their core reading program. In each activity, students have an opportunity to respond, but if they cannot produce a correct answer, the computer gives them progressive scaffolding until they can reach the right answer. For some activities, the student responds directly on the computer. For other activities, the student responds to the tutor, who records whether the student's response was correct or not, and provides individualized explanations and help if the child runs into trouble. Specific activities that students encounter are as follows:

1. Letter Sounding. The computer shows a letter, and the student must say the letter sound.
2. Letter Identification. The computer gives a letter sound, and the student must type or write the letter or letter combination.
3. Auditory Blending. The computer presents sounds for 2, 3, or 4-phoneme words, which the student blends into a word for the tutor.
4. Auditory Segmenting. The computer says a word and the student must break it into its separate sounds for the tutor.
5. Sight Words. The computer displays sight words, which the student reads to the tutor.

6. Word-Level Blending. The computer displays a word and the student uses sound blending to decode it to the tutor.
7. Spelling. The computer says a word and the student types it. At higher levels, the computer reads a sentence that the student must type.
8. Story Preparation. Before the child reads a decodable story book, the computer displays story-related words for the student to practice. This activity is particularly important for ELLs, who can learn the story vocabulary before they encounter it in a book.
9. Tracking. The student reads a story on the screen to the tutor, and uses an arrow key to track word by word. The computer models appropriate decoding strategies if the student cannot decode a word, and orally presents sight words that the student does not know.
10. Fluency. The student reads a story to the tutor, who notes errors and times to compute words correct per minute. Fluency practice and assessment focuses on accuracy, then smoothness, then expression, then rate.
11. Comprehension Questions. The computer displays questions about the stories that the student has read. The student answers orally to the tutor and then writes a response.
12. Graphic Organizers. The student completes a graphic organizer to represent main ideas from the stories.

Just-in-Time Professional Development. Alphie's Alley offers just-in-time performance support for tutors in the form of video vignettes and written suggestions on how to help remediate students' particular problems. Once a diagnosis has been made about specific problems a student may have, the tutor can view a variety of intervention strategies to help remediate that problem. For example, if a tutor determines that a child has a problem with visual tracking, then the tutor can view video vignettes of other tutors modeling ways to help children learn to track. Short audiovisual vignettes provide immediate expert guidance to the tutors focused on the exact problem they are confronting.

Control Treatment

Students in the control treatment experienced Success for All, including tutoring if appropriate, without the technology elements. The use or non-use of the technology was the only factor differentiating experimental and control treatments.

Measures

Participants were individually pretested in September, 2004 and posttested in May, 2005. Specially trained testers, unaware of children's experimental assignments, administered the tests. The measures were as follows.

1. Woodcock Letter-Word Identification. (Pre, post). The Letter-Word Identification scale of the Woodcock-Johnson III Tests of Achievement was used as a pretest and again as a posttest. It requires subjects to identify isolated letters and words.
2. Woodcock Word Attack. (Post). Word Attack asks subjects to read nonsense words, as an assessment of phonetic skills.

3. Gray Oral Reading Test-Fluency. (Post). GORT-Fluency asks subjects to read connected text, and scores them on rate and accuracy.
4. Gray Oral Reading Test-Comprehension. (Post). GORT-Comprehension is a multiple-choice test based on questions asked of subjects after they read the passages used in the Fluency test.
5. Gray Oral Reading Test-Total. (Post). GORT-Total subsumes the Fluency and Comprehension subscales.

Analysis

The data were analyzed using analyses of covariance, controlling for Letter-Word Identification pretests.

Results

Tutored Students

The main focus of the study was on students who received tutoring. In Success for All, the lowest thirty per cent of first graders, based on their reading achievement, are usually assigned to tutoring.

The number of children tutored in the experimental and control groups was somewhat different, even though the number of tutors and the number of available tutoring slots were equal between the two groups. Among students with pre- and posttests, 43% of experimental and 33% of control students were tutored. This difference, also seen in the Chambers et al. (2005b) study of computer-assisted tutoring, came about because tutored children in the experimental group caught up to their grade level faster than those in the control group and were excused from tutoring at a higher rate. This allowed the tutors in the experimental group to tutor a higher percentage of their struggling students.

Table 1 summarizes the achievement data. At pretest, there were no differences between experimental and control groups ($p < .52$). On posttests, adjusted for pretests, experimental students scored higher than controls on all measures. Effect sizes (differences between adjusted means divided by unadjusted control group standard deviations) and p values were as follows: Letter-Word Identification (ES=+0.47, $p < .05$), Word Attack (ES = + 0.39, $p < .05$), Fluency (ES= +0.58, $p < .05$), Comprehension (ES= +1.02, $p < .02$), and GORT Total (ES= +0.76, $p < .02$).

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Non-Tutored Students

Students who did not receive tutoring only experienced Reading Reels, not the computer-assisted tutoring intervention. This set of comparisons is therefore a partial replication of the Chambers et al. (in press) study of embedded multimedia.

Pretest scores for experimental and control students were similar ($p < .21$). On adjusted posttests, effect sizes and p values were as follows: Letter-Word Identification (ES=+0.35, $p < .03$), Word Attack (ES=+0.27, n.s.), Fluency (ES=+0.27, $p < .07$), Comprehension (ES=+0.04, n.s.), and GORT Total (ES=+0.22, $p < .02$).

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Discussion

The data reported here support the idea that embedding technology in classroom and tutorial instruction can make a substantial difference in the reading performance of at-risk first graders. For children who received tutoring, use of the Alphie's Alley computer-assisted tutoring program and the classroom Reading Reels embedded multimedia content added more than a half standard deviation to their reading performance (median ES across four independent measures =+0.525). The largest impact in effect size terms was on comprehension, where the children who experienced the technology scored more than a full standard deviation higher than those who received the identical Success for All classroom and tutoring models without technology.

For non-tutored students, who only experienced the Reading Reels embedded multimedia content but not Alphie's Alley, outcomes were statistically significant on two measures and marginally significant on one more. The median effect size was +0.27 across the four measures. As was seen in an earlier study by Chambers et al. (in press), the effects of Reading Reels were stronger on decoding measures (Word Attack, Letter-Word Identification, Fluency) than on comprehension. This is in line with the focus of the multimedia content, which emphasizes letter sounds and sound blending strategies.

The results of this study and previous studies on embedded multimedia and computer-assisted tutoring justify optimism about the potential of technology to play a different role in education, one of enhancing rather than replacing teachers' lessons. Building on laboratory studies and theory-building work by Mayer (2001) and his colleagues, introduction of multimedia content threaded into class lessons and tutoring sessions appears to help make concepts clear and memorable to children, perhaps taking advantage of the well-established finding that linked visual and auditory content is retained better than either content alone.

Future investigations should also focus on understanding the motivational processes by which embedded multimedia enhances learning. For example, it might be useful to explore whether the self-efficacy and self-regulation of students and tutors increase over time with use of technology-enhanced curricula. Teachers and tutors reported enthusiastic responses of students to both types of technology, and this could have affected student motivation. Other investigations should explore the relationship between the quality and quantity of technology use and achievement outcomes.

The research on embedded technology suggests that educators can take advantage of untapped cognitive capacity held by children, including those at risk. The applications of this idea that have been evaluated so far only scratch the surface; the same concepts could work in any subject at any grade level, and could be applied to help teachers with other beginning and advanced reading skills. Much work remains to be done to understand how technology can best add to teachers' instruction and how to apply this concept more broadly, but the studies done to date in beginning reading suggest that further investigation is likely to be fruitful.

Table 1
Outcomes for Tutored Students

	N	Pre	Post	Adj. Post	ES
Letter-Word ID					
Exp mean	32	366.72	423.41	424.35	+0.47*
(SD)		(26.00)	(21.29)		
Control mean	28	370.75	415.29	414.35	
(SD)		(21.16)	(21.17)		
Word Attack					
Exp mean	32		478.81	479.32	+0.39*
(SD)			(11.61)		
Control mean	28		473.29	472.71	
(SD)			(16.82)		
Fluency					
Exp mean	32		5.91	6.11	+0.58*
(SD)			(6.98)		
Control mean	28		3.29	3.06	
(SD)			(5.28)		
Comprehension					
Exp mean	32		3.84	3.96	+1.02*
(SD)			(4.13)		
Control mean	28		2.29	2.15	
(SD)			(1.78)		
GORT Total					
Exp mean	32		9.75	10.07	+0.76*
(SD)			(10.18)		
Control mean	28		5.57	5.20	
(SD)			(6.39)		

*$p < .05$

Table 2 Outcomes for Non-Tutored Students					
	N	Pre	Post	Adj. Post	ES
Letter-Word ID					
Exp mean	43	398.72	450.98	448.80	+0.35*
(SD)		(22.33)	(22.51)		
Control mean	56	392.54	438.86	440.53	
(SD)		(25.89)	(23.85)		
Word Attack					
Exp mean	43		490.21	489.22	+0.27
(SD)			(15.59)		
Control mean	56		484.88	485.64	
(SD)			(13.43)		
Fluency					
Exp mean	43		20.28	19.00	+0.27[a]
(SD)			(12.76)		
Control mean	56		14.45	15.43	
(SD)			(13.28)		
Comprehension					
Exp mean	43		6.95	6.58	+0.04
(SD)			(6.88)		
Control mean	56		6.05	6.34	
(SD)			(5.72)		
GORT Total					
Exp mean	43		27.23	25.59	+0.22*
(SD)			(16.97)		
Control mean	56		20.50	21.76	
(SD)			(17.67)		

[a] $p < .10$
* $p < .05$

Notes

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