



WATERFORD EARLY LEARNING

Characterizing the Effectiveness of the Waterford Early Learning Programs

Research Overview, Orientation, and Findings

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EARLY LITERACY SKILLS AND U.S. READING INSTRUCTION

While some progress has been made in recent years, it is clear that a large percentage of students continue to struggle with basic reading skills during their first years in school, and that these difficulties can result in deficits that remain, or grow, in the later grades (Cunningham and Stanovich, 1997; Whitehurst, 2003; Pressley, 1998). Early reading difficulties can sometimes appear even before a child enters kindergarten; language and word learning skills seem to be significantly affected by early family experience (Hart & Risley, 1995). Whether a problem begins during or before the time a child starts school, research has noted that large differences in reading technique and achievement are made apparent as early as first grade (Stanovich, 2000). Students behind during the first years of school tend to learn at a slower rate than students who begin ahead; often, this results in a so-called “Matthew effect” for reading skills, in which the academically “rich” become richer and the “poor” become poorer (Walberg, 2003).

While acquiring basic literacy skills has long been considered among the most important elements of early childhood education, many recent efforts to improve reading instruction in U.S. primary schools have not met with encouraging results, especially among lower-performing students (Viteritti, 2004, p. 69; Guthrie & Springer, 2004; Cohen, Raudenbush, & Ball, 2003). In 2005, the National Assessment of Educational Progress (NAEP) reported that more than one-third of American 4th-grade students performed at the lowest level (Below Basic) on the NAEP reading skills test, a measure of reading comprehension (National Center for Education Statistics [NCES], 2008). Recent efforts to improve reading instruction on a national scale (like the No Child Left Behind Act and its Early Reading First program) have moved public schools toward setting more specific goals for accountability and instructional methods for reading (Department of Education, 2008). Results from recent Federal efforts, while encouraging in certain areas, have not proven to be unequivocally positive; scores from the 2009 NAEP show that progress in early reading achievement continues to be very slow, even though progress has been made by lower-performing students in the early grades. The 2009 test showed no significant changes in racial/ethnic gaps, gender gaps, or gaps by type of school when compared to scores from 2007, and reading average scores among fourth-graders did not improve at all (NCES, 2010). The relative stagnation of reading scores is especially notable when compared to the success of recent initiatives in areas like early mathematics. Clearly, making improvements to early reading instruction continues to present a significant problem for both educators and policymakers.

Because early reading has proven to be such a difficult educational problem to address, it is reasonable to expect future solutions to provide more rigorous theoretical and empirical justification for their usefulness than has often been required in the past. The need for better solutions should occasion a more thorough examination of all educational tools currently used in early reading classrooms, including computer technology. While computer programs for early education are popular and widespread in today’s educational environments, these programs should be implemented as part of a school curriculum, a school readiness program, or a home-based supplement to the school curriculum, only if their relative strengths (such as interactivity and adaptability) can be utilized to improve children’s learning, and only if their content is held to similar, or higher, standards than more traditional instructional methods. The solution under examination here is the Waterford Reading curriculum (formerly Waterford Early Reading Program or WERP), a computer-adaptive software package designed specifically to teach pre-literacy and early literacy skills to beginning readers. This document outlines both the theoretical framework for Waterford Reading and the results from an initial battery of empirical testing; because we believe the Waterford software to represent an immediate and sizable opportunity for effecting change in both the classroom and the home, our aim is to provide a rationale for its further testing, funding, and implementation.

THE ROLE OF TECHNOLOGY IN READING INSTRUCTION

For children in and prior to the early primary grades, reading instruction has long been the primary focus of computerized instruction, likely because reading acquisition has been shown to be closely related to later academic achievement in a variety of subjects (National Reading Panel, 2000). Computer-assisted instruction (CAI) in the classroom allows for a dynamic presentation of material, individualized instruction, and a level of engagement in the learning process that may not be possible in a more traditional classroom setting. CAI can provide immediate feedback to responses, reinforcement where appropriate, and, in some cases, an adaptive, learner-centered course of instruction. These benefits have been related to substantive student gains in knowledge (Lepper & Gurtner, 1989; Wengling, 1998) and may help eliminate certain impediments to effective intervention among younger students and children at-risk (e.g., Fish et al., 2008).

Not surprisingly, of course, not all CAI is created equal. Just as changes to teaching technique can make a huge difference in student growth in the classroom (e.g., Bloom, 1984), both the technique used to present CAI material and the content itself must be considered. While a large number of studies have demonstrated that using CAI can be effective for supporting reading development (Wise, Ring, & Olson, 2000; MacArthur, Ferretti, Okolo, & Cavalier, 2001; Hecht & Close, 2002; Cassady & Smith, 2003) and phonological awareness (Foster et al., 1994; Reitsma & Wesseling, 1998; Mitchell & Fox, 2001; Macaruso & Walker, 2008), many researchers are still skeptical that computerized systems can provide reading instruction at the level of a human teacher in the classroom (e.g., Blok, Oostdam, Otter, & Overmaat, 2002).

Because using technology for reading instruction has not always proven to be effective, in recent years leading CAI developers have focused on programs that seek to combine short reading passages with more direct learner involvement, generally with the goal of more closely emulating the instructional methods of a human teacher or tutor. This kind of CAI, in contrast to other types of educational software, offers both flexibility for accommodating individual student differences and a definite, sequential course of instruction (Park & Lee, 2007). As mentioned previously, general research examining the effectiveness of adaptive, sequence-based CAI has been very positive. The use of adaptive learning systems in early education classrooms has resulted in greater reading ability gains compared to controls for kindergartners living in poverty (Hecht and Close, 2002), English-language-learning kindergartners (Powers & Price-Johnson, 2006), suburban kindergartners (Cassady & Smith, 2003; Macaruso & Walker, 2008), and suburban first graders (Cassady & Smith, 2005; Macaruso, Hook, & McCabe, 2006; Savage, Abrami, Hipps, & Deault, 2009). Adaptive learning systems have also been demonstrated to significantly increase phonemic awareness in low-performing preschoolers (Mitchell & Fox, 2001), at-risk preschoolers and kindergartners (Lonigan et al., 2003), and typical preschoolers (Foster, et al., 1994) compared to a control groups not utilizing CAI. A more recent meta-analysis exploring the use of adaptive CAI in Europe and Asia found an overall effect size 1.05 (Camnalbur & Erdogan, 2008).

The Waterford Early Learning Software

The Waterford Institute, a nonprofit research center founded in 1976 with the goal of providing high-quality educational models, programs, and software, began developing its Waterford Early Learning products in the early 1990s. The Waterford Reading program, first released by the Institute in 1998, offers a comprehensive computer-adaptive reading curriculum for pre-kindergarten through 2nd-grade students. Waterford Reading is divided into three levels, each of which is designed to address reading skills at a specific grade level; children will encounter material from earlier or later levels if they demonstrate themselves to be behind or ahead of other students in their age group. The program is intended to offer a complete pre-reading and reading curriculum for

these grades. Although often used in conjunction with traditional classroom instruction, Waterford Reading also provides offline student and teacher components, and can therefore be used as a comprehensive, stand-alone curriculum.

The Waterford Reading software presents a wide range of multimedia-based activities in an adaptive sequence tailored to each student's initial placement and his or her individual rate of growth. Its instructional "strands" include phonological awareness, phonics, comprehension and vocabulary, reading fluency and language concepts (i.e., print concepts, grammar, and mechanics of written and spoken language).

According to some researchers, it is the cumulative, sequential nature of reading skills that accounts for much of the difficulty lower-performing students experience when trying to catch up to their peers (Bast & Reitsma, 1998; Snow et al, 1998). Fluent reading and comprehension require students to have acquired a core set of early skills, many of which build on one another and need to be learned more or less in order (Heuston, 2008). These observations have led to the so-called "causal" model of early reading skills: early-appearing abilities like phonological awareness are thought to facilitate decoding, which in turn facilitates word recognition, which in conjunction with listening comprehension determines reading comprehension (Stanovich, 2000).

In order to account for this complex but largely sequential process, the Early Reading Program adapts its instruction both within and between activities; the program is capable of delaying the introduction of new concepts if sufficient progress has not been made in other areas, even if the two are not in the same instructional "strand". What follows is a description of the major areas that Waterford Reading has been designed to address.

Phonological and Phonemic Awareness

Phonological and phonemic awareness refer to the ability to parse the sounds of language into increasingly smaller units. These abilities often appear earliest and are considered among the most important for a child's transition from speaker to reader. Phonological awareness, the more rudimentary skill, has been defined as the general appreciation of the sounds of speech as distinct from their meaning (Snow et al, 1998). Because it has proven to be very important for the development of a number of later reading skills—as well as widely predictive of successful reading comprehension later in life—phonological awareness is strongly emphasized in both educational literature and the development of new instructional techniques (National Reading Panel, 2000). Phonemic awareness, defined as an understanding that words can be divided into a sequence of sounds (phonemes), is a further refinement of earlier phonological awareness skills (see Snow, 1998).

While basic phonological awareness has been described as more of a school-readiness skill, many teachers and educational programs begin explicit instruction in phonemic awareness when a child is in kindergarten or 1st grade. Because the development of phonological and phonemic awareness skills is tied causally to later pre-literacy skills, falling behind due to inadequate or inappropriate instruction may have a considerable effect on a child's progress in the subsequent months and years (Snow et al, 1998). As such, Waterford Reading places a unique emphasis on phonological skills: once children begin phonological awareness with Waterford Reading, activities from this "strand" are presented and remediated every time a child uses software.

The Alphabetic Principle and Decoding

Phonological skills lead either directly or indirectly toward an understanding of the alphabetic principle, which Stanovich (2000) points to as a "discovery" that letters on the page correspond to or map out word sounds.

The skill known as decoding, then, refers to the process of identifying the sounds of each of a word's graphemic (written) components. A child is said to have decoded a word when he or she can pronounce—though not necessarily comprehend—all the sounds in that word. When children are just beginning to read, decoding can sometimes be so slow that even familiar word meanings will not be understood (Stanovich, 1986).

As with phonological and phonemic awareness skills, students who fall behind while learning basic decoding skills often have difficulty catching up. Children who experience difficulty “breaking the spelling-to-sound code” naturally read more slowly and begin to be exposed to less text than other peers; these difficulties combined with resulting motivational problems contribute to increasingly lower achievement (Snow et al, 1998). Strands addressing decoding skills in Waterford Reading include Phonics, Fluency and Language Conventions. Higher-order skills like fluency are only emphasized in Level Three, once a child has demonstrated a sufficient grasp of more basic decoding.

Comprehension and Vocabulary

Phonological and decoding skills together constitute what has been called a “map” for comprehending written language. It is by these abilities, rather than by comprehension abilities per se, that children are most often constrained by in the early grades. According to some research, nearly all children in the early grades are capable of understanding the content of what they are asked to read, but deficiencies or slowness with more basic reading skills can sometimes prevent them from doing so (Gough, Hoover, & Peterson, 1996). The NAEP results cited above clearly demonstrate that comprehension, if not as often a problem for students when they begin school, can present considerable difficulties of its own in subsequent years (see NCES, 2008; 2010). Other research has pointed to specific comprehension-related difficulties not thought to be related to earlier skills (Oakhill & Yuill, 1996). Waterford Reading combines vocabulary and reading comprehension material into one instructional strand, which is increasingly emphasized as children progress through the program. The software's reading comprehension and vocabulary “strand” teaches both basic word meanings and strategies for comprehending or deriving meaning from text, and is included in each level (1-3) of the program.

EFFECTIVENESS STUDIES

Because it has been designed from the ground up not only to complement traditional classroom methods but also to reflect the best in educational and developmental research, Waterford's software has always been ahead of its time. The program has been formally assessed in a variety of schools and districts of varying size, location, and socioeconomic status. While the methods, sample sizes, and measures of these studies differ widely, the results are consistent in supporting the software's considerable effectiveness. Used to facilitate and enrich classroom learning, Waterford Reading has proven to be an excellent tool for helping students and teachers reach their educational goals.

Early studies

After the development of Level 1 (kindergarten) of Waterford Reading was completed, researchers at the Institute designed a series of early effectiveness studies using a number of public and private schools in Utah—including the Institute's own school, located in Provo—and the New York City Public School System. Testing was performed at the beginning and end of the school year using Waterford's internal measure, the Waterford Early Reading Instrument (WERI). The WERI was created based on recommendations from two prominent early reading researchers, Drs. Marilyn Jager Adams and Philip Gough. These initial tests yielded positive results

reported in percentages: in every case, classes who used the software made greater gains in pre-literacy skills than comparison classrooms. Waterford students at Timpanogos Elementary, for instance, improved reading test average scores to from 50% to 91.8% over the course of the year—compared with score averages of 55% (pre-test) to 73% (post-test) among the control group. Each of the New York schools tested included large ESL (English as a Second Language) populations. These early results were the first to demonstrate the particular effectiveness of Waterford Reading for ESL students: in both of the New York schools (PS 43 in the Bronx and PS 1 in Manhattan) where largely-ESL classes used the software, these classes ended up performing better on post-tests than the English-proficient classes in the control group (60% vs. 47% on the WERI in PS 43 and 85% vs. 68% in PS 1). Researchers also noted a strong correlation between a student’s results and time spent on-task, a finding which later studies would help verify.

Case Studies

After Waterford had conducted these initial tests, a number of school districts throughout the country were invited to implement the Waterford Reading in their K-2 classrooms. Evaluation results from these schools or school districts are provided in this section.

One of the first of these case studies was conducted during the 1996-1997 school year in the Dallas Independent School District. After a one-year trial with 668 kindergartners, researchers noted highly significant differences ($p < 0.001$) between students using the Waterford program and control classrooms. Results from a study conducted in the Whittier City and Hacienda la Puente Districts in Los Angeles were similar: after a large number of kindergarten students ($N = 558$) used the program for approximately six months, analyses indicated that the average growth scores for Waterford students were significantly higher than those of comparison classes ($p = .0008$). A third study, commissioned by the State of Ohio in three Columbus-area schools, found significantly greater gains among students using Waterford Reading than a control group ($p < .05$) for skills including letter-word identification, spelling, and phonological awareness. In 1997-1998, a study in Newark public schools showed statistically significant differences in favor of Waterford Reading students group over controls ($p < .02$) on the TERA-2 standardized assessment ($N=265$). In 1999, administrators in the Decatur Illinois School District implemented Waterford Reading among kindergarten and first-grade students during two successive school years ($N=700$). First-grade students who had used Waterford Reading significantly outperformed control-group students on the Iowa Basic Test of Skills for reading ($p = .003$). Finally, after a statewide implementation of Waterford Reading ($N=2414$) in Idaho kindergartens, evaluators working in connection with the Albertson Foundation reported strong evidence from a representative sample of eight school districts for Waterford Reading’s effectiveness among academically disadvantaged students. After one year with the program, the effect size for students who had originally tested in the lowest third on standardized reading measures was 1.14, and the overall effect size for students who completed the program was 0.52.

The Los Angeles study (cited above) also provided another early indication that Waterford Reading can be particularly effective among ESL populations: the average growth rate for limited English-proficiency students using Waterford Reading was double that of the English-proficient group in letter recognition and phonological awareness. Another study in Maryland (at Glenridge Elementary School) produced similar results: ESL students benefited even more than native speakers from their use of the software, increasing their scores more than 600 percent (as compared to 283 percent for the control group). Researchers noted that using the software appeared to have significantly reduced the literacy gap between ESL and other students; later studies examining the effects of Waterford Reading on ESL students more closely have provided further support to these results.

Recent Effectiveness Studies

Recent study findings regarding the Waterford software have corroborated previous research by more thoroughly demonstrating its effectiveness in early education classrooms. The scope of these investigations has broadened as well; researchers have moved from simply testing the software's success to examining its usefulness within a wider range of learning environments. Recent studies have tested the program among kindergartners living in poverty (Hecht and Close, 2002), English-language-learning kindergartners (Powers & Price-Johnson, 2006), pre-kindergarten students (Heuston, 2010), suburban kindergartners (Cassady & Smith, 2003), and suburban first graders (Cassady & Smith, 2005). The program has demonstrated remarkable strength and adaptability under this renewed and broadened scrutiny.

Cassady and Smith published the first of their two Waterford Reading-related studies in 2003. An Indiana school implemented Waterford Reading in its kindergarten classes to work in conjunction with existing literacy instruction; the evaluation used the Phonological Abilities Tests (PAT) at three points during the trial year (beginning, middle, end) to assess student gains for basic literacy skills. Another school in the area, which had not implemented the program at all, served as the control group. Teachers in both schools, as participants in the Intentional Reading Project (IRP), were engaged in ongoing professional development activities, and both schools received various other resources throughout the year; the researchers were careful to ensure that Waterford Reading was the principal curricular difference. Despite no significant differences in pre-test scores, students using Waterford Reading experienced a faster acquisition of phonological awareness skills than students who had not used the program, $F(2, 85) = 3.05, p < .05, \eta^2 = .07$.

As a follow-up to their study with kindergartners, Cassady and Smith moved to examine the effect of Waterford Reading on reading achievement gains during the first-grade year. Again, students who used the software experienced significantly greater reading skill gains on a standardized test (the CTBS Terra Nova) than the comparison group, $F(1, 91) = 10.61, p < .002, \eta^2 = .10$. The researchers also noted that it was the lowest-performing students who benefited most from the program; these students dramatically outperformed the low-performing comparison group ($F[1, 21] = 15.67, p < .001, \eta^2 = .43$). By the end of the first-grade year, test scores among this "at-risk" group were equivalent to those of the moderate-performing students in the comparison classes.

Previous research has demonstrated that children who live in poverty are more likely to develop reading and spelling impairments than other children (e.g., Bowey, 1995). Hecht and Close (2002) investigated the use of Waterford Reading by one such group of disadvantaged kindergartners, comparing their pre-literacy gains over the course of the year to a class that had not used the program. Assessments used included a number of well-known standardized measures, among them the Wide Range Achievement Test, the Stanford-Binet, the Stones—Concepts About Print Test, the Woodcock-Johnson Tests of Achievement (Form B), and the Comprehensive Test of Phonological Processing. Analyses showed that the Waterford Reading class significantly outperformed the comparison group in phonemic awareness tests (with effect sizes of 1.14 and 1.13 for the skills of phonemic segmenting and blending, respectively) as well as invented spelling (effect size = 1.198) and word reading (effect size = 1.114). The researchers also noted that the amount of time children spent with the Waterford Reading was an important factor for its success: more time spent with the software uniquely contributed to performance in phonemic awareness, invented spelling, letter knowledge, and print concepts.

Powers and Price-Johnson (2007) recently completed a large-scale study of Waterford Reading among fifteen kindergarten classes from Tucson, Arizona's Unified School District. Results showed that the students who used Waterford Reading ($N = 358$) significantly outperformed a large comparison group ($N = 1480$) on both the

Dynamic Indicators of Basic Early Literacy Skills (DIBELS) ($F [1, 1846] = 20.23, p < .001$) and Core Curriculum Standard Assessment (CCSA) tests ($F [1, 1887] = 20.80, p < .001$). The researchers then disaggregated the data by school, gender, ethnicity, primary home language, and other measures. Waterford Reading was found particularly effective for students who were classified as English language learners; these groups posted greater gains than the English-proficient group in the comparison schools ($F [1, 1045] = 8.62, p = .003$).

RESULTS FROM THE UPSTART PROGRAM (2009-2010)

The UPSTART program, first supported by the state of Utah to test home-based computer software among preschool-aged children, provided for an entirely new environment for measuring the effectiveness of the Waterford Reading curriculum. Testing among pre-school children was important because, although the software is designed to accommodate children of this age, all previous tests of Waterford Reading had taken place among kindergarten or early primary students. UPSTART began in 2009 and was implemented to some degree in every public school district throughout the state. Substantial efforts were made to reach low-income and minority students: 61 percent of UPSTART participants in 2009-10 came from lower-income homes, and 20 percent classified their ethnicities as non-white. The program also provided state funding for the installation of computers and Internet access in a large number of homes.

As part of the evaluation, a large number of UPSTART children ($N = 1,347$) used a version of the Waterford Reading curriculum that had been designed for home use. Students were asked to spend fifteen minutes a day with the software, five days a week, until the time they entered kindergarten. Because UPSTART was created specifically to teach reading, math and science for pre-kindergarten students, only results from Level One of Waterford Reading were considered for the evaluation. Gains were measured using a web-based reading assessment called the Waterford Assessment of Core Skills (WACS). Due to attrition effects (i.e., some children did not take the WACS post-test, and others took neither the pre-test nor the post-test), the analyses included usage data and test scores for 784 students.

Among the principal hypotheses for the UPSTART study was that increased time with the Waterford Reading curriculum would result in corresponding increases in pre- to post-test gains. Among the 784 children who took both the pre-test and the post-test, average usage (once outliers were eliminated) was approximately 13.80 minutes per calendar day, more than 30% more than the recommended proxy value of 10.71 minutes per calendar day. Once outliers were removed, analysis results showed that the use of Waterford Reading was a significant predictor ($p < .000$; Adj. $R^2 = .093$) of early-reading achievement gains (Heuston, 2010). Additionally, it was found that children who had used the program for less than the recommended time experienced only small gains on the WACS test ($M=11.8, SD=316.7$) when compared to children who used the program for about the right amount of time ($M=163.1, SD=346.5$) and children who used the program for significantly more than the right amount of time ($M=263.5, SD=350.3$). Finally, the time children took to master skills decreased as their compliance to recommended usage increased ($p < .000$), suggesting that the relative rate of learning increased as children spent more time with Waterford Reading.

RESEARCH HIGHLIGHTS

Among the most consistent and salient findings from these studies is that Waterford Reading has proven to be particularly effective among disadvantaged and minority students. Results from the Cassidy and Smith, Hecht and Close, and Powers and Price-Johnson studies speak to the software’s striking effectiveness at helping “at-risk” or low-performing students catch up with their peers; earlier case studies in Utah and Texas found significantly greater gains among lower-performing students as well. Evaluators have also noted the differential effectiveness of Waterford Reading for non-native English speakers. Results from studies conducted in New York, California, Maryland, and Arizona have all provided evidence that the program is even more effective among this group than it is for English-proficient students.

Another notable finding, observed by several researchers, is that increased time on task with Waterford software seems to strongly increase student gains. Analyses conducted by Hecht and Close and Powers and Price-Johnson, as well as the UPSTART evaluation, each yielded a strong, positive correlation between time using the Waterford program and reading skill gains. These findings lend further support to the Institute’s design approach, which relates “mastery” of a sequence of tasks to each student’s time-on-task (see Bloom, 1984; Stanovich, 2000). As demonstrated by the success of the UPSTART program, Waterford Reading has also shown itself to be strongly adaptable to home-based and pre-school environments. Home-based education is generally considered to lack both a clear structure and the necessary instructional expertise; because the software is adaptive and has been guided by early literacy research, Waterford Reading is well-positioned to help children acquire beginning reading skills before they enter school.

The consistency of these research results, both within and between studies, is perhaps what is most striking when it comes to evaluating the program. In each of the studies detailed here, students in classrooms using Waterford Reading outperformed comparison-group classes in most, if not all, of the examined assessment measures. In no case did the comparison-group outperform Waterford students. Waterford has always focused its development and iteration on research; because of this, its software has demonstrated remarkable strength, robustness, and adaptability. Results have been consistent in a wide variety of early-education contexts—and regardless of which assessments have been used. Despite the challenges faced by educators in implementing educational technology in the classroom, it has become increasingly evident that carefully-crafted, adaptive instructional technology is capable of yielding serious results. Waterford’s software is, above all, a considerable and flexible tool for helping children reach their whole potential.

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