

# Technology Tools to Support Reading in the Digital Age

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*Gina Biancarosa and Gina G. Griffiths*

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## Summary

Advances in digital technologies are dramatically altering the texts and tools available to teachers and students. These technological advances have created excitement among many for their potential to be used as instructional tools for literacy education. Yet with the promise of these advances come issues that can exacerbate the literacy challenges identified in the other articles in this issue.

In this article Gina Biancarosa and Gina Griffiths characterize how literacy demands have changed in the digital age and how challenges identified in other articles in the issue intersect with these new demands. Rather than seeing technology as something to be fit into an already crowded education agenda, Biancarosa and Griffiths argue that technology can be conceptualized as affording tools that teachers can deploy in their quest to create young readers who possess the higher levels of literacy skills and background knowledge demanded by today's information-based society.

Biancarosa and Griffiths draw on research to highlight some of the ways technology has been used to build the skills and knowledge needed both by children who are learning to read and by those who have progressed to reading to learn. In their review of the research, Biancarosa and Griffiths focus on the hardware and software used to display and interface with digital text, or what they term e-reading technology. Drawing on studies of e-reading technology and computer technology more broadly, they also reflect on the very real, practical challenges to optimal use of e-reading technology.

The authors conclude by presenting four recommendations to help schools and school systems meet some of the challenges that come with investing in e-reading technology: use only technologies that support Universal Design for Learning; choose evidence-based tools; provide technology users with systemic supports; and capitalize on the data capacities and volume of information that technology provides.

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Technological advances are dramatically altering the texts and tools available to students and teachers. Since 2007, the number of devices available for displaying digital text has increased exponentially.<sup>1</sup> The first e-reader to take hold in the market, the Amazon Kindle, sold out two days after it was released in November 2007.<sup>2</sup> By June 2011, Amazon reported selling more Kindle books than hard- and soft-back books combined.<sup>3</sup> Meanwhile, the first large-scale release of a touchscreen tablet, the Apple iPad in April 2010, further expanded options for readers to access digital-text media with its inclusion of the application “iBooks.”<sup>4</sup> By the time the iPad 2 was released in March 2011, more than 15 million units had already sold, and by June 2011 that number was 27 million.<sup>5</sup> Analysts forecast that 89.5 million units, including both tablets and e-readers, will sell worldwide in 2014.<sup>6</sup>

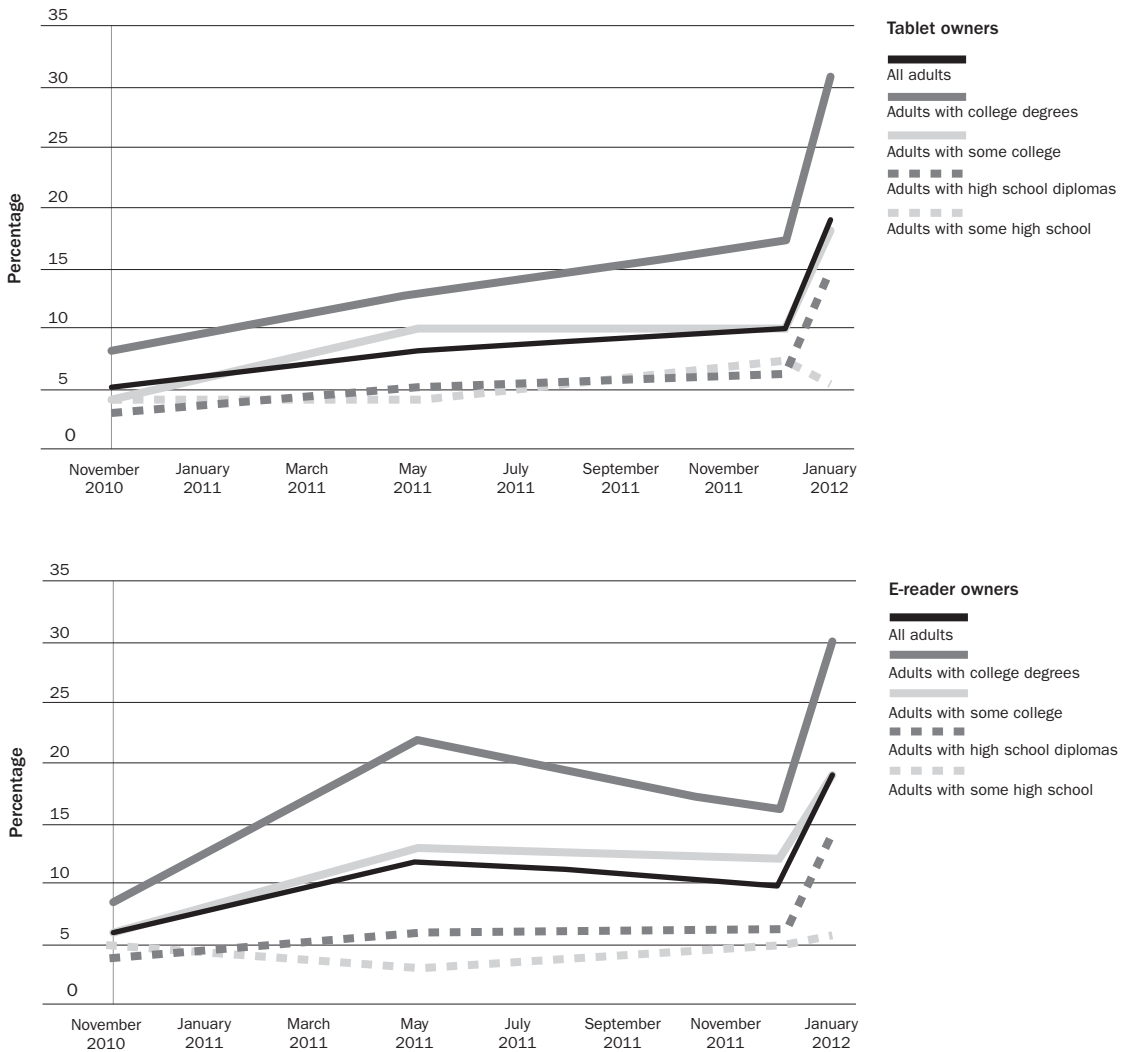
These technological advances have created high hopes among many teachers, administrators, researchers, and policy makers, who believe that the digital devices offer great promise as instructional tools for literacy education. Simple applications of existing e-reading technology such as changing font size on-screen, using text-to-speech features to provide dual input of text, or using the Internet to collaborate on learning activities may substantially improve the learning of many students.<sup>7</sup> At the 2011 annual International Conference on Computers in Education, researchers from around the world met to exchange ideas on more-advanced uses of e-reading technology, ranging from providing individualized feedback through artificially intelligent animated avatars, to fostering critical thinking skills through computer-supported collaboration, to predicting students’ interest or frustration

based on brain-wave signals and mouse-click behavior.<sup>8</sup>

Yet with the promise of these advances come issues that can further exacerbate the literacy challenges that are identified in other articles in this volume, such as gaps in the literacy skills of students of different socioeconomic status. Nonie Lesaux, for example, highlights the importance of higher-level conceptual skills and knowledge for literacy, and she stresses the need to narrow gaps in those areas by providing all students with adequate opportunities to develop such knowledge.<sup>9</sup> The new e-technology, however, may inadvertently widen such gaps. Parents, for example, increasingly use technology to provide their children with learning and reading opportunities—and today’s parents are the fastest-growing population of consumers purchasing e-reading technology. But parents are not equally able to provide those opportunities for their children.<sup>10</sup> As figure 1 depicts, ownership of tablets and e-readers is surging, with sales doubling over six months in 2011 and doubling again in the final month of 2011.<sup>11</sup> But as figure 1 also illustrates, purchasing patterns indicate a widening education-based gap in access, a gap that also exists when purchasing patterns are disaggregated by income level.<sup>12</sup> The resulting technology gap closely resembles the demographically based literacy-skills gap outlined in the article in this issue by Sean Reardon, Rachel Valentino, and Kenneth Shores, thus raising the worrisome possibility that new technologies for developing literacy skills will pose further difficulties for students from low-income families.<sup>13</sup>

And even if policy makers and educators address gaps in access to technology, experts warn that achievement disparities may continue to widen unless students are given

Figure 1. Changing Percentages of Tablet and E-reader Ownership by Education Level



Sources: Pew Internet and American Life Project.

sufficient opportunities to learn how to use the technology to accomplish a wide range of goals. Although demographic gaps in access to technology at home are being narrowed by students' improving access at schools, libraries, and community technology centers, serious gaps remain in students' ability to use technology in sophisticated ways.<sup>14</sup> High-achieving students are not only more likely to use technology for interest-driven activities

such as researching topics or collaborating online to create new media, but are also more likely to have adult guidance in its use.<sup>15</sup> Lower-achieving students are more likely to use it for socially driven activities such as chatting or playing games with friends using social media, following pop-ups, or surfing through links of celebrities and sports figures.<sup>16</sup>

Such differences in the way students use technology may not only do little to shrink knowledge gaps, but may in fact exacerbate them. Students need more than access to technology; they need to learn how to apply it strategically to advance their literacy skills—especially the conceptual and knowledge-based capacities that become crucial in later literacy tasks. In her article in this issue, Susan Goldman describes how having to navigate vast amounts of unfiltered information at various levels of complexity and in different forms can complicate learning for students who are already struggling to master strategic approaches to reading and critical thinking skills.<sup>17</sup>

Although the need for students to master literacy skills and knowledge is not new to the digital age, the urgency of that need is amplified by technology. The question is not the narrow one of how to fit technology into literacy education, but the broader one of how to transform literacy education to meet today's changing demands.

The good news is that technology can be a tool for mitigating many literacy challenges. It is already being used in new and promising ways to address the full range of skills, both procedural and conceptual, required for improving student literacy. That is, technology can be more than a tool for drilling students on skills; it can be a tool for acquiring the vocabulary and background knowledge essential to becoming a skilled reader. Although technology is no panacea for literacy problems, it can be part of the solution. For its promise to be realized, however, its tools must be embedded strategically within cohesive, evidence-based educational programs.

In this article we examine how teachers are using reading technology to address

the literacy challenges highlighted in other articles in this issue. Though many early literacy technologies have thus far focused on basic reading skills, we explore how technology can build knowledge and support higher-level reading strategies and behaviors. We address key systemic issues facing educators and policy makers in their efforts to make reading technology a tool for improving literacy rather than yet another source of inequity, and we conclude with recommendations about how to maximize the benefits of investments in e-reading technology tools. We begin by clarifying terminology.

### Defining E-reading Technology

In both popular media and research, terms such as e-book, e-reader, e-text, and tablet are not always clearly and consistently differentiated and are often used interchangeably. The lack of clarity in part reflects the rapid advance of technology, with newly released options almost immediately being modified or merged together with other options. Such change contributes to confusion as distinguishing features become vague or obsolete.

This slippery terminology can be perplexing for educators, parents, and policy makers who need to make well-informed decisions about these technologies. Although we focus on the digital text, we note, as Goldman indicates in her article in this volume, that it is often augmented by other digital media and so is increasingly difficult to isolate from other media.

In this article, we use e-reading technology to refer to the hardware and software used to display and interface with digital text. Hardware includes devices, such as e-readers and tablets, as well as smartphones, laptops, and even desktop computers, that display digital text. Software includes a range of

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applications and programs that allow readers to interact with the text, either locally on the device or over a network; it may or may not include instructional features. Although many forms of e-reading technology may be used for more than reading, we focus on the technology's role in literacy instruction. And although many other technologies, including audio players, video players, interactive whiteboards, and clickers, may be used for literacy instruction, they cannot store and display digital text.<sup>18</sup> We confine the term e-reading technology to those that can. Nascent research on these other technologies, although promising, is thus beyond the scope of this article.<sup>19</sup>

Using such a broad term makes it hard to draw generalized conclusions from research, because each device and application has specific features and limitations. Thus, claims made about one form of e-reading technology with specific features may not apply to another form. For example, when researchers conduct an efficacy study using tablets with a specific instructional application, it may not be possible to generalize their findings to smartphones or laptops, even with the same application, not least because of the vast differences in screen size.

## **Research on E-reading Technology as a Tool**

Today educators are in the precarious position of having to respond to the many new e-reading options for curriculum and teaching practices with virtually no empirical guidance on how to do so in a way that supports learning. Most research as yet is small-scale in nature, focusing on feasibility and efficacy in tightly controlled contexts rather than on wide-scale use. We review a variety of small-scale research studies on e-reading technology as a tool for improving literacy outcomes, and then look at two large-scale studies and offer a final cautionary note about the overall lack of a consistent or large-scale body of evidence on e-reading technology.

## **Tools for Compensation and Instruction in Basic Skills**

E-reading technology has shown promise in developing early reading skills and in giving readers with visual impairments or language-based disabilities access to texts. One of its most widely used features is text-to-speech, in which either a human or computer-generated voice reads digital text aloud for users. Sometimes synchronized highlighting of the text draws readers' attention to the word or words being read aloud.

The research is relatively robust on the benefits of text-to-speech for readers with impairments that might otherwise preclude equal access to text and for young readers still acquiring basic skills like phonological awareness or decoding.<sup>20</sup> Also promising are recent innovations in text-to-speech involving the translation of visual information other than text, such as pictures or tables.<sup>21</sup>

Ofra Korat has been conducting experimental studies with e-reading tools that can build both procedural skills (such as phonological

awareness and word reading) and conceptual skills and knowledge (such as vocabulary) that foster learning to read. She has found that presenting children's books as digital text with dictionaries or activities can lead to improvements in phonological awareness, word-reading skills, and vocabulary knowledge for kindergarten and first-grade readers.<sup>22</sup> Other studies with younger children indicate that presenting high-quality children's books on computers with multimedia supports, such as the text being read aloud expressively with simultaneous highlighting of the words being read, helps to improve children's focus on and subsequent recognition of words from the text, as well as their vocabulary.<sup>23</sup>

Others have investigated the use of similar e-reading technology tools to provide practice opportunities and individualized feedback for struggling and impaired readers and found promising results.<sup>24</sup> Richard Olson and his colleagues provide further evidence that struggling readers in grades two to five can benefit from programs that provide individualized e-reading practice opportunities in story reading, comprehension strategies, and phonological analysis.<sup>25</sup> Another strand of research, which has focused on embedding multimedia practice opportunities into e-reading technology that can be sent home with students, finds that the technology increases children's, especially at-risk children's, practice at home.<sup>26</sup> One small-scale study found that children from lower socioeconomic backgrounds benefited more from such opportunities than did more-advantaged children and that they made greater gains in both word-recognition skills and vocabulary knowledge, thus suggesting that e-reading technology could be useful for closing both procedural and conceptual skill gaps in literacy.<sup>27</sup>

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Research with somewhat older readers has also found positive results of e-reading technology for a range of reading skills, including fluency, vocabulary, and comprehension. Jack Mostow and his colleagues at Carnegie Mellon University have developed a computer-guided reading tutor that builds readers' fluency and comprehension using speech-recognition to give spoken and graphical feedback as students read instructional texts aloud.<sup>28</sup> They have also found that second-language readers show improvements in fluency and spelling skills comparable to or greater than those obtained with English as a Second Language instruction alone.<sup>29</sup> A similar program called Scientific Learning Reading Assistant has also generated evidence that speech-recognition applications within e-reading programs can improve oral reading fluency skills in second- through fifth-grade readers.<sup>30</sup> Finally, a synthesis of the research on e-books, defined as digital texts that mimicked print texts (for example, having pages that turn), has found small positive effects for prekindergarten to fifth-grade students' comprehension-related outcomes.<sup>31</sup>



### **Tools for Supporting Strategic Readers**

Innovative technology applications also show promise for supporting the development of advanced reading skills that students need to master discipline-specific knowledge areas and that may be particularly challenging for students from low socioeconomic backgrounds and non-English-speaking homes. Self-paced tutorials have led to gains in self-questioning, error detection, inference, summarization, and concept-mapping skills and strategies to enhance readers' use of reading strategies and comprehension of texts. Two online interventions, Computer Assisted Strategy Teaching and Learning Environment and Improving Comprehension Online, have both shown positive effects in these skill areas in quasi-experimental studies. Sixth graders using Computer Assisted Strategy Teaching and Learning Environment outperform controls in application of the targeted strategies. Benefits can depend on genre, with treatment students outperforming on expository versus narrative texts or vice versa depending on the strategy under consideration.<sup>32</sup> Monolingual and bilingual fifth-graders using Improving Comprehension Online have shown improvement relative to control students on norm-referenced and research-developed measures of vocabulary.<sup>33</sup> Students in grades six through twelve have largely endorsed online tutors and self-paced tutorials as desirable features of e-books.<sup>34</sup>

Experimental evaluation of instructional agents—generally, animated avatars that respond to student input in digital text or human or computerized voices—has demonstrated particular benefit for boosting vocabulary, identifying inferences, developing metacognitive awareness regarding understanding, and learning appropriate strategies.<sup>35</sup> The instructional agents respond with

clear, immediate, and individual corrective feedback that mimics teachers but on a scale that individual teachers cannot hope to replicate, thus improving a teacher's ability to provide just-in-time individualized support to an entire class of diverse students. Moreover, these agents have become increasingly sophisticated over the past decade, and some can now respond to spoken natural language.<sup>36</sup> Digital delivery of graphic organizers that provide readers with a structure for strategically interacting with the text has also been shown to improve comprehension.<sup>37</sup>

### **Tools for Building Knowledge and Supporting Reading to Learn**

Digital text gives educators access to tools that allow more flexibility regarding content selection and layout of the text, as well as the means to modify content based on the particular needs of students and local communities. The use of ancillary materials such as original source documents and alternative multimedia presentations of information has helped compensate for struggling readers' limitations in background knowledge and has enriched learning opportunities for all readers.<sup>38</sup> For example, teachers can use online multimedia resources from respected sources, such as PBS and National Geographic, to augment their presentation of new content to all students and as a tool to build background knowledge for students who lack it.<sup>39</sup>

Manipulable embedded graphics have been associated with improved outcomes in science learning and have also been shown to support iterative conceptual development, allowing students, for example, to interact with a graphic or even an animated representation of repeated random sampling to understand the Central Limit Theorem, a foundational but difficult-to-grasp concept in statistics.<sup>40</sup>

Online learning communities can also support individualized pursuit of learning interests beyond the classroom.<sup>41</sup> Innovative work using chat functions allows students to collaborate and interact to solve online problems.<sup>42</sup> Connections to digital repositories enable students to access authentic source materials such as scanned original letters exchanged between writers of the Declaration of Independence or recorded speeches by public figures such as Martin Luther King Jr.<sup>43</sup>

Positive outcomes for improving background knowledge, strategic use of technology, and innovative applications of technology have also been shown in evaluations of Community Technology Centers, community-based services located in independent facilities or embedded in public libraries and after-school programs such as Boys and Girls Clubs.<sup>44</sup> These centers provide students access to a variety of up-to-date equipment and high-speed Internet access that, coupled with workshops and mentoring from staff, allow the youth to learn to use technology for a variety of purposes.<sup>45</sup>

### **Tools for Individualizing Supports**

Other articles in this issue explore how disparities in students' skills and knowledge, combined with reading and learning impairments, complicate the task of improving literacy outcomes for all learners. Teachers charged with delivering differentiated instruction to meet the individualized needs of learners must often do so by trying to retrofit a one-size-fits-all curriculum—to meet the needs of diverse learners—a cumbersome and time-consuming process.<sup>46</sup> Moreover, unless carefully designed, e-reading technology itself can replicate the problem, thus reproducing old barriers and generating new ones that marginalize diverse learners.

CAST (originally the Center for Applied Special Technology) uses an approach called Universal Design for Learning (UDL) to design e-reading technology that attempts to meet the needs of individual learners by assuming and taking into account their diverse needs.<sup>47</sup> A key aspect of UDL is to provide multiple ways both for students to gain knowledge and skills and also for them to express and apply that knowledge. In the case of e-reading technology, tools like text-to-speech, automated tutors, and individualized levels of support are built into e-reading applications from the beginning rather than being added later. Although the concept of UDL itself is not new, technological advances increase the feasibility of providing a wide range of supports to meet the needs of every learner. Research on matching students to technologies is still at an early stage.

### **Tools for Assessment**

E-reading technology, particularly its instructional applications, often incorporates mechanisms for gathering data on students. The data may be restricted to use patterns, such as frequency and duration of use, or it may extend to assessment of learning by incorporating placement and mastery assessments. Because studies of e-reading instructional tools have not examined whether they are as effective with assessment as without it, we review briefly a few examples from the wide and increasing range of technological innovations for literacy assessment. Because space does not permit a full discussion of these innovations, we must overlook important ones such as clickers, automated scoring of written and spoken answers, and innovative assessments of higher-level comprehension skills.<sup>48</sup>

One of the most popular tools for assessment in literacy (and beyond) has been



computer-adaptive testing (CAT). Regarded as an innovation a decade ago, CAT has become a mainstay of large testing firms. The Educational Testing Service regularly uses it for online tests, and reading achievement tests, including the Computer Based Assessment System for Reading, Measures of Academic Progress, Scholastic Reading Inventory, and STAR Reading, are increasingly available in online CAT formats. Many states, including Florida, Maryland, and Oregon, have invested in online CAT systems for one or more state accountability tests. What CAT offers is an assessment that adapts to the test-taker. Students who answer questions correctly are given questions of increasing difficulty, while students who respond incorrectly are given questions of decreasing difficulty. Each student thus completes a large number of items at her or his difficulty level, leading to a more precise estimate of the underlying ability being assessed. Although some observers have raised concerns that early careless errors may lead to underestimates of student abilities, recent evidence suggests that such underestimation is rare and occurs primarily for students of very high or very low ability.<sup>49</sup>

The turn to computerized delivery of assessments has raised concerns that such assessment, adaptive or not, might pose particular difficulties for anxious test-takers or those with less computer experience. Although evidence is limited, comparisons of adults taking the GRE suggest that anxiety is a strong predictor of performance and that computing confidence is a weak but significant predictor—but also that neither depends on the format in which a test is delivered.<sup>50</sup> Other research with adults suggests that older adults may comprehend less and read less efficiently using computer screens than using paper, whereas younger adults show no difference.<sup>51</sup> Studies with intermediate, middle, and high school

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students have had mixed findings. Two indicate that the medium of test administration does not significantly alter results, but a third finds that computerized tests take longer to complete but yield significantly higher scores.<sup>52</sup> In assessments of writing, by contrast, greater familiarity with computers predicts better performance even when paper-based writing ability is taken into account.<sup>53</sup>

More recent innovations in assessment have involved hand-held devices on which teachers record assessment information, ranging from scores alone to item-level student responses. In many cases, companies offering applications for these devices have adapted pre-existing assessments, such as Wireless Generation's adaptation of the Dynamic Indicators of Basic Early Literacy Skills. Others have developed unique measures for hand-held devices and have created applications for teachers to record data from their own self-created formative assessments, but research on the effects of these approaches is lacking.<sup>54</sup>

Assessment through e-reading technology may soon become standard practice. The U.S. Department of Education has invested heavily in developing online assessments, funding two large multistate consortia to develop assessment systems aligned to the Common

Core State Standards—the Partnership for the Assessment of Readiness for College and Careers and the SMARTER Balanced Assessment Consortium. Two smaller consortia, the Dynamic Learning Maps and the National Center and State Collaborative, focus exclusively on assessments for students with special needs. The assessments developed by all four of these consortia will be delivered online and are due for initial implementation by the 2014–15 academic year.

### Large-Scale Studies: A Cautionary Note

Although e-reading technology offers real promise for improving literacy outcomes, evidence of its effectiveness is relatively limited. As of early 2012, out of 321 literacy-intervention programs reviewed by the What Works Clearinghouse over a decade, only thirteen relied on e-reading technology to some extent.<sup>55</sup> Of these, six were deemed to have at least potentially positive effects with no overriding contrary evidence, but both the number of studies of the six interventions and the overall sample sizes for each were generally small. Only Read 180 in grades four through nine and SuccessMaker in grades four through ten had a medium to large research base; both had small positive effects on reading comprehension.<sup>56</sup>

In fact, only two large-scale studies of e-reading technology tools have been conducted as of early 2012; thus we review them in detail here. Both provide sobering evidence that should temper excitement about rapidly advancing technological innovations and thus emphasize the importance of explicitly and thoroughly evaluating effectiveness, as well as the importance of considering what promotes full implementation.

In 2009, the Institute for Educational Sciences released findings from a federally funded

randomized control study that investigated the effectiveness of ten reading and mathematical software programs used in first- and fourth-grade classrooms.<sup>57</sup> Researchers measured outcomes by comparing student scores on state-mandated standardized tests in classrooms where the programs were integrated with the curriculum with scores in classrooms where the programs were not used. Only one reading program resulted in statistically significantly improved outcomes in fourth grade, and these effects were small and not evident until its second year of use. None of the other reading or math programs led to significant differences in scores when compared with the “business as usual” instructional programs.<sup>58</sup>

In another federally funded, large-scale, randomized control trial published in 2011, researchers investigated Thinking Reader—an e-reading computer program for nine children’s novels that provides instruction, guided practice, and feedback to readers at one of five teacher-chosen individualized levels of support. The study compared outcomes of sixth-grade students who participated in the intervention with those of control students who received regular instruction and found no significant differences.<sup>59</sup>

In short, the two studies provide no evidence that large-scale implementation of e-reading technology improves educational outcomes. But they do raise issues that should be addressed in ongoing research into the effectiveness of the technology. The first study, for example, evaluated programs that used very different approaches to instruction, making it unclear whether the failure to find effects for most programs was attributable to the technology or to the instructional approach. Nor was it clear whether the

programs under study were complementary to and connected with daily instruction in treatment classrooms—a particularly important consideration in making sustained, purposeful, and effective use of the technology to improve reading. Neither was it clear how faithfully the programs were implemented in the intervention classrooms. Because schools and districts were selected precisely for their inexperience with such tools, lack of experience and discomfort with technology may also have contributed to the predominantly null findings.

The Thinking Reader study raised another important issue by gathering data on how students used the program. It found that the frequency of use was nowhere near suggested levels—about 60 minutes a week rather than the recommended 110 to 165 minutes. And although Thinking Reader designers recommend that students participating in the program read multiple novels, the study found that by the end of the school year, 12 percent of students had not even begun a novel, 20 percent had not finished their first novel, 31 percent had completed only one, and only 7 percent had completed a third.

One explanation for the failure of large-scale studies to find evidence that e-reading technology is effective may thus be that positive outcomes depend as much on genuinely engaging teachers and their students in the use of e-reading tools as on the availability of the technology itself. Whereas efficacy trials of programs and devices tend to target eager users by default, generating positive outcomes in large-scale studies and in the field may require more concerted attention to how these tools can be made appealing and useful to less-than-optimally eager and knowledgeable users.

## **Practical Challenges to E-reading Technology Use**

Maximizing the potential benefits of e-reading technology also poses practical challenges. To realize fully the technology's promise, schools will need to buttress infrastructural supports, including professional development for teachers, systems for upgrading and maintaining technology, and efficient and secure data systems.

## **Professional Development**

Technology has made its way so quickly into so many facets of modern life because of its utility. Being able to pay bills, order clothing, send a message to a friend, and read a newspaper article within less than an hour and without leaving home is appealing to many people. The technological advances that have made their way into education have done so for the same reason. The overhead projector enabled teachers to share information more efficiently with their classes while interacting with students more directly. The scientific calculator allowed students to learn more advanced math and science concepts by using more efficient methods of calculation. Teachers and parents now routinely communicate by e-mail. For e-reading technology to realize its promise fully, it must be genuinely useful to both the teacher and the student.

All too often, integrating technology into education has meant simply adding it to the existing curriculum and pedagogy, thereby limiting its usefulness for teaching and learning. Rarely is technology an organic part of a lesson plan, especially as more and more requirements to administer in-class accountability tests absorb already-limited class time. According to Project Tomorrow 2010, the educators who see technology as being important to a district's core purpose are those who are farthest from daily

engagement with students. Some 60 percent of district administrators and 55 percent of school principals endorsed the idea of technology's importance, but only 38 percent of teachers and future teachers did so.<sup>60</sup> In fact, educators often view technology skills not so much as a means for advancing learning and supporting instruction, but as just one more item on the list of things that students must learn, that teachers must make time to teach, and that administrators must squeeze into an already overly restrictive budget.<sup>61</sup>

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Not surprisingly, when researchers surveyed schools that had high access to, but low use of, technology, they found that teachers had limited time to find and evaluate software; that computer and software training was inconveniently timed or was too generic and not specific to the needs of teachers; and that most teachers were using the technology without fundamentally changing their instructional strategies to take full advantage of it.<sup>62</sup> In addition, the most recent federal survey of teachers' use of technology found that although many use it for record-keeping, relatively few use it for instruction. Generally speaking, teachers in schools serving large numbers of low-income students use technology less for instruction than do teachers in schools serving fewer such students, except to

teach or provide practice in basic skills.<sup>63</sup> Most important, two-thirds of teachers reported little to no technology-related professional development in the preceding year.

For teachers to see e-reading technology as useful, they need help adjusting to and capitalizing on the changing technological landscape. They need not only to see the potential benefits for themselves and their students, but also to be able to build the knowledge and skills to realize these benefits and to have opportunities to collaborate and innovate with colleagues to develop and integrate best practices.<sup>64</sup> The extent to which an individual teacher uses technology depends on how long it takes to learn to use it, how convenient it is to interact with it, and how well the technology interacts with other devices. If technology is to be used in the schools, it must offer user-friendly and intuitive interfaces, portability of content between devices, and timely, skilled response to technical challenges both by developers and by schools. Ongoing professional development, including training and testing of new technology as it becomes available, helps accelerate the learning curve for teachers, so that they can focus on using these tools to improve instruction.

Evidence on the best approaches to and efficacy of professional development in support of e-reading technology use, however, is in short supply. Teachers most commonly report that what prepared them to make effective use of technology for instruction was not training, but independent learning.<sup>65</sup> Indeed, some have argued for a coaching or mentoring approach to professional development in using educational technology effectively, with development focused on problems of practice.<sup>66</sup> But, again, evidence about how

effective coaching models are in professional development of that sort is minimal,<sup>67</sup> although some research does suggest that coaching models in literacy instruction more broadly improve literacy outcomes for students.<sup>68</sup>

### **Equipment and Systems Upgrades and Maintenance**

As options for using e-reading technology for educational purposes proliferate, school systems are struggling to provide equitable access to e-reading devices, texts, and appropriate technological supports. A system of governance that needs to protect limited funds faces the need to continually upgrade technological supports and infrastructure. Meanwhile students across demographic categories report that the available technology resources at school are unsophisticated.<sup>69</sup>

The unprecedented rate of technological change can create a sense of urgency to adopt the latest innovation without attending to how new tools affect students, teachers, professional development, and infrastructure systems. For example, schools frequently lack the advanced hardware and Internet bandwidth needed to use the most innovative software, applications, and web pages.<sup>70</sup> Although e-mail and most web browsing require only 50 kilobytes per second (kbps), television-quality streaming video requires 250 kbps, and interactive videos require 300 kbps.<sup>71</sup> And these requirements are for each user. Indeed, the Consortium for School Networking estimates that an 800-student high school with 50 faculty and staff needs 7.45 megabytes per second to handle expected traffic.<sup>72</sup> Schools must keep pace with the ever-increasing processing and bandwidth demands so that they can not only leverage the latest e-reading technology, but also keep abreast of the changing workplace

and real-world technological demands as they prepare their students for life after school.

### **Data Accessibility, Usability, and Security**

E-reading technology offers educators time-efficient tools for gathering, accessing, and interpreting data needed to produce the assessments essential to decision making. Used effectively, electronic assessments can minimize the time teachers need to take away from instruction and practice and maximize the timeliness of the information they use to tailor instruction to students' individual needs. Technology offers administrators and policy makers multiple coordinated data sources to improve their understanding of their education systems. And it can enrich research efforts to investigate the match between students and services and how they evolve over time.

Two types of systems capture information. Learning management systems deliver instructional content to users, whether students engaged in reading or other learning tasks or teachers engaged in professional development. These record-keeping systems usually track learners' engagement with content as well as their performance on linked content-related assessments. By contrast, student information systems offer a database approach to keeping track of a wide range of student information, including assessment scores, grades, schedules, attendance, and more—a modern alternative to the filing cabinets that historically have lined the walls of school and district central offices.

Although developers of both types of tools have tried to build efficiencies into the systems, teachers and other educators often receive little training in how to use them, particularly in the service of improved instruction. Despite developers' clear



recommendations to include end users in implementation plans, a mere 30 percent of surveyed school information-technology leaders reported that teachers were represented on core implementation teams, and an even smaller share reported demonstrating how to integrate tools into instruction and assessment.<sup>73</sup> Although school and district leaders generally believe training for teachers is adequate, teachers report that it does not match their daily needs for aligning instruction to assessment results.<sup>74</sup>

Student data in particular raise issues of protecting student safety, well-being, and civil rights. Students and their parents should have choices about what data is collected, how it is used, and with whom it is shared. The Federal Education Rights and Privacy Act of 1974, which was enacted to protect student privacy, does not yet adequately address the increased risks to privacy associated with Internet connectivity.<sup>75</sup> School systems will therefore also need to bolster and improve online security on an ongoing basis to keep up with threats to student privacy.

## Policy Recommendations

Despite the limited evidence base for the effectiveness of e-reading technology, it is nevertheless possible to suggest specific policies to help schools use the technology to support improved literacy outcomes for all students. The following policy recommendations are informed not only by the research base, but also by discussion with authors and editors of this issue of the *Future of Children* and with a panel convened by the Carnegie Corporation of New York that included representatives of educator advocacy groups, reading researchers, educational publishers, and e-reading technology developers. We thus make the following four recommendations based on collaborative, grounded

discussions on how to capitalize on the promise of e-reading technology as well as on the research to date.

Our first recommendation is that school systems should insist on e-reading technology that incorporates Universal Design for Learning. Only technology that supports UDL is flexible enough to fulfill one of e-reading technology's core promises: helping teachers support diverse learners. Although several e-reading technology applications already incorporate many UDL features, those features are not yet universally available and often are limited to text-to-speech. And while text-to-speech has by far the most research supporting its efficacy, it cannot by itself meet the full range of learner needs. Policy makers should require that funds devoted to e-reading technology be used only for devices and programs that support UDL and have the capacity to individualize support features. Specific criteria and procedures for complying with UDL are available from the National Instructional Materials Accessibility Standard and the National Center on Universal Design for Learning.<sup>76</sup>

Our second recommendation for schools is to choose evidence-based tools. Because e-reading technology is proliferating and diversifying so rapidly, research evidence will necessarily lag behind innovations. Thus, choices of e-reading technology tools must be guided by research both on the technology itself and on effective instructional practices. The research on e-reading technology that we have reviewed relies heavily on practices with an extant pretechnology research base—for example, explicit instruction, modeling, and guided and independent practice opportunities. For small investments in e-reading technology, an evidence base that is not rooted in the technological application



may be sufficient. But for large investments, school systems should require independent scientific evidence of effectiveness or, when that is not possible, arrange for researchers or third-party evaluators to study the technology's effectiveness as soon as it first is implemented. Policy makers should be very cautious when considering investments in innovative practices, such as virtual learning environments, that were not possible before e-reading technology. Meanwhile, federal and private grant makers should encourage precisely such innovation, always incorporating research on effectiveness.

Our third recommendation is that schools provide systemic supports. To use e-reading technology tools effectively, teachers need adequate and consistent systemic support, such as formal school-based information-technology teams. These teams should be familiar not only with the technology, but also with how it should be used within the curriculum and how to support teachers and others who use it. Technical support should include regularly scheduled updates and servicing to ensure security and prevent problems; it should also give teachers rapid response to troubleshooting requests. Policy makers and administrators should consult organizations such as the Consortium of School Networking and State Educational Technology Directors Association for up-to-date advice and estimates on infrastructure and costs associated with supporting bandwidth and other needs raised by e-reading technology.<sup>77</sup>

The needed systemic supports also include professional development for teachers, specialists, librarians, and other school faculty and staff. Because teacher training begins in college teacher preparation programs, these programs must move to incorporate regular

use of e-reading technology. Teacher candidates should use this technology not only as learners, but also as instructors; that is, they should be given opportunities to use it both to learn and to teach. Given the breakneck speed of technological advance, no teacher preparation program will ever be able to keep teachers fully up-to-date in the shifting technological landscape. Schools must thus invest in professional development that helps teachers to use adopted technology to its utmost. As with any effective professional development, these opportunities need to be ongoing and responsive to local problems of practice.

Our fourth recommendation for schools is to capitalize on data. One of the clearest strengths of e-reading technology is in gathering and reporting student data. Teachers require timely data at their fingertips to inform their instruction and intervention decisions. This requirement is made all the more pressing by the current widespread investments by states in Response to Intervention models wherein schools use screening and progress-monitoring assessments to make ongoing decisions about the nature and intensity of supports provided to struggling students. As school systems modernize their data systems, it has become feasible for teachers serving students from pre-kindergarten through postsecondary levels to access the data they need to ensure more seamless transitions between grades and schools—for example, the transition from pre-kindergarten to kindergarten or from middle school to high school. Similarly, monitoring agencies, such as districts and states, will have increasingly timely access to evaluation and other outcome data. And not least, these data streams open up a world of possibilities for research by enabling analysts to take into account students' educational

histories in investigating how and why various practices and interventions work differently for different students.

The increasing wealth of data available through e-reading technology can be perceived either as a burden or as an opportunity to discover how to serve the learning needs of varied populations both locally and for the field more generally. In particular, this wealth of data affords opportunities to investigate how effects of e-reading technology are influenced by key variables that have been largely overlooked, such as teacher experience with technology, consonance of technology tools with the curriculum, and facilitators and barriers to optimal intended use of technology. Policy makers and federal and private funders should provide incentives to school districts and universities to collaborate not only with each other in capitalizing on data, but also with educational publishers and e-reading technology developers, so that information about the design of such innovations can flow in both directions.

## **Conclusion**

Our aim in this article has been to examine how today's changing technological landscape offers both promise and challenges to literacy instruction. The question is not how to fit technology into education but how literacy education can meet society's increasing

demand for technology-savvy citizens who possess higher levels of literacy skills and background knowledge. Our intent has been to highlight issues that educators, researchers, and policy makers must consider in responding to those demands.

The good news is that e-reading technology offers many tools for mitigating both old and new literacy challenges. But e-reading technology tools are just that—tools. To be effective, they must be wielded with care and precision. Not every nail requires a nail gun; sometimes a hammer will do. Similarly, not every literacy problem requires e-reading technology to solve it. Although e-reading technology can be used to deliver rich and meaningful content, it may not support learning unless thoughtful human beings are guiding its use.

We believe that e-reading technology tools can help to improve literacy outcomes for all children and youth. In creating policies and investing in e-reading technology, policy makers, administrators, and educators must ensure the technology's adherence to the Universal Design for Learning concept, attend carefully to the technology's evidence base, provide the infrastructure the technology requires, and take maximum advantage of the increased efficiency and volume of information that technology provides.

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