Improving Adult Literacy Instruction: Options for Practice and Research (2012)

Chapter: 6 Technology to Promote Adult Literacy

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Technology to Promote Adult Literacy

In this chapter, we examine the types of technologies that are available or could be developed for adult literacy instruction. Part one presents classes of technologies that are available and could be used to support growth in adults' literacy skills. Part two describes why these technologies would be expected to improve learning and literacy skill development. Part three describes specific digital tools and instructional approaches for practicing literacy skills. The chapter concludes with a summary and discussion of directions for research.

We argue from the findings that technologies can be designed and used to scaffold literacy growth in ways that may not occur in available forms of interaction between human teachers and students. Although it is likely that using technologies will add to the cost of literacy programs, the degree of differentiated and sustained support adults need to develop their skills is great enough that investments in technology may be the most cost-effective solution. Thus, it is worth developing and testing the most promising new approaches so that their costs and benefits are better understood.

In reviewing the research, we recognize that many studies of technology effectiveness in education show minimal and sometimes null results. This is not surprising. Technology does not of itself produce learning. It simply amplifies and extends instructional strategies. Too often, studies of technology effectiveness have paid inadequate attention to the content of the instruction and assumed that amplifying any strategy would be effective. Neither do the studies attend sufficiently to the engineering and training required to implement the technologies effectively.

In this chapter, we describe promising technologies that, if well engineered and supported, could be used to amplify effective instructional approaches. In some cases, we provide clear supporting evidence; in other cases, the evidence is indirect, and efficacy studies are needed. In virtually every case, translational research will be needed to demonstrate how the technologies can be part of coherent systems of instruction. We point to all of these technologies because of their potential to alleviate some of the barriers adults experience with learning due to restricted times and places of in-person instruction. Rising education costs also make amplification of human effort especially important in fields, such as adult education, that lack a strong funding base.

Furthermore, adults need opportunities to access tools and develop proficiencies that are part of what it means to be literate in the 21st century. As described in Chapter 2, literacy always includes a mediating technology that makes possible the inscription and transmission of words and meanings, whether a stone tablet, a quill pen, a book, a typewriter, or a word processor. What is new in the digital age—and what makes it essential to emphasize the role of new technologies in efforts to promote adolescent and adult literacy—is the unprecedented nature, speed, and scale of change in technologies for literacy that have occurred as a result of the Internet and related information technologies, commonly referred to as Web 2.0.

An assessment by the editors of the *Handbook of Research on New Literacies*, a compendium devoted to an exploration of new technologies, provides a sense of the vast shifts now occurring as a result of the Internet (Coiro et al., 2009a, pp. 2-3):

> No previous technology for literacy has been adopted by so many, in so many different places, in such a short period, and with such profound consequences. No previous technology for literacy permits the immediate dissemination of even newer technologies of literacy to every person on the Internet by connecting to a single link on a screen. Finally, no previous technology for literacy has provided access to so much information that is so useful, to so many people, in the history of the world. The sudden appearance of a new technology for literacy as powerful as the Internet has required us to look at the issue of new literacy with fresh lenses.

Many researchers in literacy and related fields are actively investigating the implications of Internet and related information and communication technologies (ICTs) for literacy, schooling, civic engagement, and work. To name a few such efforts, there is interest in the strategies that readers use for comprehending text online (e.g., Coiro and Dobler, 2007); multimodal text production and comprehension (e.g., Hull and Nelson, 2005; Jewitt and Kress, 2003); identifying and developing new online spaces that provide opportunities for language learning and literacy development (e.g.,

Hull, Stornaiuolo, and Sahni, 2010; Lam, 2000); and documenting the startling growth and new patterns of use of digital technologies, including cell phones and social networking sites, in mostly out-of-school contexts (Ito et al., 2009; Pew Internet & American Life Project, see http://www.pewinternet.org/ [Jan. 2012]).

There are several constraints on the evidence available. Currently, out-of-school uses of digital technologies for communication, selfpresentation (on such sites as Facebook), work, and play far outstrip their use in schools for educational purposes. Educational institutions can lag greatly in their uptake and appropriation of new literacy tools and practices (Beach, Hull, and O'Brien, in press; Davies and Merchant, 2009; Greenhow, Robelia, and Hughes, 2009), thereby limiting the available research. With few exceptions, such as studies of the out-of-school digital literacy practices of youth (Hull et al., 2006; Ito et al., 2009; Lam, 2000; Lankshear and Knobel, 2003), which are only time-bound snapshots, the research base on ways to use new technologies outside classrooms to develop adults' literacy also is slight.

Certain factors have constrained the use and study of technologies for adult learning. Historically, adult education has been underresourced, in terms of both access to literacy-related technologies and instructional tools and teachers skilled in their instructional use. Currently, some populations still lack Internet connectivity and access to instructional uses of digital technologies, although such gaps are quickly narrowing (Pew Internet & American Life Project, see http://www.pewinternet.org/ [Jan. 2012]). The technology usage studies described earlier, for example, may not generalize to the adult literacy learner population, or they may apply to only part of that population. Technology access for learning also can be a complex matter. Although access to technologies for particular subgroups of learners needs to be verified and understood better,[1] we turn next to the large landscape of technologies for learning that are potentially available to adolescents and adults who need to enhance their literacy. Most are readily accessible on the Internet.

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[1]An interesting example of the underlying complexity of availability arose in an urban school near one committee member. In that school, a foundation provides laptops for the students. However, only students whose parents attend weekend orientation sessions may take the computers home. So, all students have some access, but the subset with greater access has parents able and willing to attend a couple Saturday sessions. Many students have computers at home, but other family members compete for them and they may not contain support for instructional affordances.

CLASSES OF TECHNOLOGIES FOR LEARNING

A report of the National Research Council (2008) identified 10 classes of technologies for learning:

1. conventional computer-based training,
2. multimedia,
3. interactive simulation,
4. hypertext and hypermedia,
5. intelligent tutoring systems,
6. inquiry-based information retrieval,
7. animated pedagogical agents,
8. virtual environments with agents,
9. serious games, and
10. computer-supported collaborative learning.

To this list must be added the everyday tools of word processing. The ability to easily and quickly compose and edit prose is a major determiner of writing achievement, and word processing tools replace laborious writing and complete rewriting with faster (after practice) typing and editing that does not require recopying the entire written product (see

Berninger et al., 1998; Christensen, 2005; Graham, Harris, and Fink, 2000; Graham, Harris, and Fink-Chorzempa, 2002).

Most of the items on the list above (3-10) were not widely available 20 years ago, and most are not mainstream technologies in schools today. Many of these technologies are unfamiliar to and unavailable to adult learners, particularly those with low literacy. This means that learning systems, like systems used for marketing and other commercial purposes, need highly intuitive interfaces and modes of learning activity. The labels, icons, graphics, layout, and semiotic foundations of symbols need to be easily understood and generally fully accessible without training or instruction manuals. This often is not the case for instructional technologies (Yeh, Gregory, and Ritter, 2010). It is likely that many such uses of technology that could be productive have proven disappointing in initial tests because of poor design or because a potential body of users was not part of the subculture that has absorbed knowledge of how to use a given technology. (For example, 10 years ago, high school students generally did not need instructions in how to use cell phones, but senior citizens sometimes did, because the high school culture had learned about cell phones but the senior culture had not yet absorbed this knowledge.)

One general problem in evaluating evidence on uses of technology is that the first efforts to use an approach are often designed by small teams that lack the full range of skills to make software usable, even when they have a powerful concept. Rigorous tests of the first efforts then yield minimal results, making it harder for subsequent design teams to get the funds needed to produce truly usable systems. Increasingly, tools to make software more usable are becoming more usable themselves, and it may be worth reconsidering some approaches that showed minimal results if it appears that part of the problem was poor design.

Still, many adolescents and adults in the United States and across the world (but possibly not all adult literacy learners) have adopted with alacrity and ease digital technologies for everyday life that have become inexpensive and readily available, such as cell phones. Furthermore, the literature on adolescent literacy has documented many cases of young people who acquire facility with digital tools that require reading and writing in their out-of-school lives and who have more digital expertise than teachers, although they may experience difficulties with academic literacy. The widespread use of digital tools associated with literacy in everyday life may provide a means to scaffold the development of competencies in print-based and academic literacy genres; research is needed to determine how. The existence and widespread use of such tools also challenge educators and educational institutions to expand definitions of literacy and opportunities to practice literacy to include a facility with online and multimodal texts and technologies. A related need is research on how to assess competencies with digital texts.

HOW TECHNOLOGIES AFFECT LEARNING

Computer technologies may improve learning for many reasons. They can be adaptive to the profiles of individual learners, give the learner control over the learning experience, better engage the learner, and be more efficient on many dimensions. A number of researchers have reported advantages of particular classes of technologies compared with classroom instruction, reading textbooks, and other judiciously selected controls.

For example, Dodds and Fletcher (2004; Fletcher, 2003) conducted a meta-analysis of studies with primarily adult learners that showed an advantage over controls for conventional computer-based training (.39 σ effect size), multimedia presentations (.50 σ), and intelligent tutoring systems (1.08 σ). The subject matters represented in these meta-analyses included mathematics, science, and procedural knowledge rather than reading or writing per se. Mayer (2005) reported advantages (~1.00 σ) of multimedia over conventional text on science/technology content; he also identified cognitive principles that explain when multimedia presentations do or do not help.

Successful intelligent tutoring systems have been developed to teach well-formed topics in mathematics, including algebra, geometry, and programming languages (The Cognitive Tutors—Anderson et al., 1995; Koedinger et al., 1997; Ritter et al., 2007); physics (Andes, Atlas, and Why/Atlas—VanLehn et al., 2002, 2007); electronics (Gott and Lesgold, 2000; Lesgold and Nahemow, 2001); and information technology (Mitrovic, Martin, and Suraweera, 2007). These systems do not target reading and literacy per se, but the scientific, mathematical, and technical content covered is presumably a close fit to the verbal materials that adults use in the real world and are likely to invoke and develop aspects of verbal skill related to reading and literacy skill. The systems show impressive learning gains (~1.00 σ), particularly for deeper levels of comprehension in subject areas.

Not every type of advanced computer technology has been demonstrated to facilitate learning in every subject area. Indeed, more needs to be understood about many of these technologies. Learning gains have either been nonsignificant or mixed in major investigations of hypertext/ hypermedia (Azevedo, 2005; Azevedo and Cromley, 2004), animation and interactive simulation (Ainsworth, 2008; Dillon and Gabbard, 1998; Tversky, Morrison, and Betramcourt, 2002), and inquiry-based information retrieval (Goldman et al., 2003; Graesser and McNamara, in press; Klahr, 2002). This may be because most learners have inadequate strategies for inquiry learning; that is, they do not know how to use new information tools for the purposes that have been tested. Research is only emerging on the effectiveness of serious games (Kebritchi, Hirumi, and Bai, 2010; O'Neil, Wainess, and Baker, 2005; Ritterfeld, Cody, and Vorderer, 2008), virtual environments (Johnson and Beal, 2005; Johnson and Valente, 2008), and computer-supported collaborative learning (Bereiter and Scardamalia, 2003). Much remains to be explored about whether these environments can play a productive role in adult literacy improvement.

Computerized learning environments have been developed that directly focus on reading and writing. McNamara's edited volume (2007a) describes many of the recent systems that have been developed, such as iSTART, to promote deeper levels of comprehension, and Carla (Wise and VanVuuren, 2007), which focuses on more shallow levels. These computer environments as a group help students learn reading at multiple levels, including language decoding, vocabulary, semantic interpretation of sentences, generating inferences, and building self-explanations of the content. Learning gains in such system have been statistically significant, although effect sizes tend to be lower than those for mathematics and other science and technology areas. At the same time, we note that reading trainers that are commercially available for children did not show significant improvements in the 2007 report of What Works Clearinghouse assessments (Dynarski et al., 2007). There are questions about the quality of those evaluations, however, and

whether the interventions adequately reflected the power of the new technologies. Regarding writing, a number of computer tools give feedback and improve different aspects of the writing process, such as Summary Street (Kintsch et al., 2007), e-rater (Attali and Burstein, 2006; Burstein, 2003), and the Intelligent Essay Assessor (Landauer, Laham, and Foltz, 2000). There are fewer writing trainers than reading trainers. Research is needed on how computer tools can support the writing development of adults with low literacy, including the integration into adult education programs of Web 2.0 technologies that have become prevalent in daily life, such wikis, blogs, and social networks.

Computer-based trainers have been developed to improve metacognition, self-regulation, and critical thinking while learners interact with multimedia environments. For example, SEEK Web Tutor helps adults evaluate the quality of information sources as they try to learn from Internet-based materials (Graesser et al., 2007; Wiley et al., 2009), and MetaTutor trains students on metacognitive and self-regulated learning strategies (Azevedo et al., 2009). These skills are important in the unedited Internet culture, in which the quality of many information sources is suspect and the goals of reading comprehension vary substantially (McCrudden and Schraw, 2007; Rouet, 2006). The impact of these trainers on comprehension and learning has either been modest or has not been fully evaluated, however.

An example of a tool now readily usable for instruction is onscreen agents that act as mini-tutors to help with using a technology or to provide other assistance. Modern learning environments increasingly incorporate animated conversation agents that speak, point, gesture, walk, and exhibit facial expressions. Agent-based systems have shown impressive learning gains, with moderate-to-high effect sizes (Atkinson, 2002; Gholson and Craig, 2006; Gholson et al., 2009; Graesser, Jeon, and Dufty, 2008; Hu and Graesser, 2004; McNamara et al., 2007b; Moreno and Mayer, 2004, 2007). The potential power of these agents is that they can mimic face-to-face communication with human tutors, instructors, mentors, peers, or people who serve other roles (Baylor and Kim, 2005). Ensembles of agents can model social interaction. Both single agents and ensembles of agents can be carefully choreographed to mimic and reflect on virtually any strategy connected to reading, writing, and learning. Agent-based systems are easy for low-literate adults to use because the human-computer interface naturally mimics everyday social experiences.

In addition to onscreen agents, there is the opportunity for human tutors to interact with students online via real-time chats, such as those that are increasingly available to support visitors to banking, shopping, and other websites. Although technologies have been used to provide real-time reading and writing instruction (e.g., such instruction was organized for children in the wake of the Haiti earthquake), the committee did not locate research on the use of real-time chats in the educational settings. Such technologies are worth testing for adult literacy programs because they allow flexible, immediate, and scaffolded interactions with instructors outside the classroom setting.

DIGITAL TOOLS FOR PRACTICING SKILLS

In the sections that follow, we describe some of the possible ways that technologies might enhance adult and adolescent literacy practice and acquisition. Many of these technologies have yet to be tested with adult literacy learners, so a program of empirical research to evaluate their effectiveness and how best to implement them is highly recommended. Nevertheless, there is empirical research that shows the promise of these technologies in K-12 and college populations.

Group collaborative communication software. In this category, we include the kinds of tools that are used in offices every day. Especially helpful to adult learning, perhaps, are the tools that are starting to emerge for exchanging comments on written materials. Other frequent forms of collaborative communication include electronic calendars, email, text messaging, Facebook, wikis, and collaboration portals. New technologies for group communication are appearing regularly.

Word processing software. The most basic tools that can help with literacy are standard word processing tools, which facilitate writing and especially editing. With a little practice, students can quickly get ideas on paper and then sharpen them. Having ideas in machine-processable form also makes it possible to use the latest tools for exchanging ideas and working in teams on written products. Controversies remain about features of software that make it easy to circumvent mastery of some literacy skills, notably spelling correction. However, for most adults and adolescents who have limited literacy, the ability to get ideas on paper, read those of others, edit initial writing, and exchange ideas that sharpen comprehension and composition is dramatically enhanced by word processing tools and should therefore be encouraged (Bereiter and Scardamalia, 2003; Graham and Perin, 2007a). In the end, the single best-established fact about literacy is that it is a form of skilled expertise, and such skills require thousands of hours of effective practice. Word processing tools support that practice. Related tools, such as presentation software, are standard ways by which empowered adults express their literacy in civic and work situations. Part of being functionally literate today is the ability to use such tools effectively.

Bulletin boards and discussion tools. Once students are creating compositions and exchanging them, they need ways to hold conversations with each other about the texts. All of this is easily possible via bulletin board systems. On such systems, threads of conversation can be started about

particular topics or posted texts. Students engage in multiple literacy activities that involve reading additional documents and peer comments and then preparing their own comments and posting them. This approach is promising both because it provides engaging ways of practicing literacy and because the continuing exchanges provide natural experience with the need to write for others' understanding.

Commenting tools embedded in programs. Contemporary online word processing facilities provide commenting tools in online texts. Adobe Acrobat provides such tools for commenting on PDF files, but there also are software packages on wiki or Moodle sites that allow students to annotate texts individually as they read. Students can benefit from seeing which parts of a text prompt annotations and what their peers wrote in their notes. This turns reading into an enterprise in which quality effort is reified by artifacts and supported with those artifact tools. The use of commenting tools also mimics productive work, providing both motivation and practice in some of the 21st-century skills. For example, the chapters in this report accumulated over 100 comments each during their initial development and later editing, even prior to the formal review stage.

Virtual meeting tools. A variety of new systems support online meetings with components that permit word processing and other tools to be shared over a network. That is, multiple people can talk to each other, write to each other, show each other diagrams and other media, and jointly edit a single text, PowerPoint file, or other document. Back channel tools, such as chat windows, allow the meeting host to structure the interactions and ensure that anyone who wishes to make a point or enact a change in a document is given a chance to do so. While current systems are probably too expensive for general school use (largely because of communications charges), the price of in-house tools that could be used on a school building network can be expected to drop rapidly, following the cost curve of most new technologies.

Virtual meeting tools are used in the work world partly to support working from home. In the education world, especially for adult learners, such tools can help in overcoming transportation issues, increasing total engaged time beyond short class periods, and, for adolescents, better connecting home and after-school environments to school settings. Preliminary design and feasibility research are needed to provide a clear picture of what is possible and whether actual learning gains would be as large as one might predict.

Speech-to-text and text-to-speech tools. Computer-generated speech (called text-to-speech) and speech recognition facilities (called speech-to-text) occur throughout society (Jurafsky and Martin, 2008). Phone calls are answered by computers that then respond to spoken commands by consumers. High-end automobiles can respond to hundreds of voice commands, generally without training to handle a specific person's voice. It is entirely possible to develop texts that read themselves to a student and also systems that listen to students reading texts aloud and give corrective assistance if they make errors in their reading (Cole et al., 2003; Johnson and Valente, 2008; Mostow, 2008). A number of intelligent tutoring systems allow spoken student input as an alternative to typed input (D'Mello et al., 2010; Litman et al., 2006).

Speech-to-text technologies are achieving an acceptable level of accuracy because the speech processing task in shadowing oral reading is highly constrained. One knows what the reader should be saying, and hence it is straightforward to monitor actual student speech and correct it when appropriate. Other assistive possibilities exist as well. The computer jumps in and pronounces a word on which a student stumbles. The computer orally restates a sentence or two after a student gets stuck, thereby helping out when processing capacity is limited.

Technologies with text-to-speech and speech-to-text facilities are growing at a fast pace. Additional capabilities are described below in the section on Electronic Entertainment Technologies and Related Tools.

Embedding low-level coaching in electronic texts. Related to natural language processing technologies is the possibility of embedding pop-up questions in texts that are presented on screen. This is one way to prompt students who may get caught up in word recognition to also engage in meaning. Variations of this approach were developed at the Centre for Educational Technology in Israel two decades ago (observed by Alan Lesgold; no documentation known but screen images are available), and other variants were developed in the United States, such as Point and Query (Langston and Graesser, 1993). The basic idea is that the kinds of prompts introduced in such tools as Questioning the Author (Beck et al., 1996) can be embedded in machine-readable text and then made to appear automatically alongside the text to which they apply as the student encounters it. It is possible to have pop-up questions tailored to match a system's best understanding of how the reader is processing the text in question. For example, if the student is not spending enough time on difficult content that is important, then there can be pop-up generic questions (Are you sure you understand this section?) or specific questions that target particular ideas.

Automatic essay scoring. It is commonly held that a primary reason that students are given relatively few writing assignments is that it takes instructors too long to read and comment on them. There are two easy solutions to this problem. One is supported by the tools for collaborative text processing discussed above. Specifically, students can comment on each other's work. Although there are no data on how well this works with the adolescent and adult limited literacy population, there have been demonstrations (Cho and Schunn, 2007; Cho, Schunn, and Wilson, 2006)

that it is an effective teaching strategy to have students comment on each other's written work in college courses. Positive results to date generally have involved use of writing to teach specific content rather than in literacy instruction.

In addition, it is possible to do considerable automated scoring of texts through recent advances in computational linguistics. Shermis and colleagues (2010) reviewed the performance of the three most successful automated essay grading: the e-rater system developed at Educational Testing Service (Attali and Burstein, 2006; Burstein, 2003), the Intelligent Essay Assessor developed at Pearson Knowledge Technologies (Landauer, Laham, and Foltz, 2000, 2003; Streeter et al., 2002), and the IntelliMetric Essay Scoring System developed by Vantage Learning (Elliott, 2003; Rudner, Garcia, and Welch, 2006). These systems have had exact agreements with humans as high as the mid-80s, adjacent agreements (i.e., scores the same or only one point apart in the rating scale) in the high mid-90s, and correlations as high as the mid-80s. Just as impressive, these human-machine agreement levels are slightly higher than agreement between pairs of trained human raters. Automated essay graders have been used in electronic portfolio systems to help students improve writing by giving them feedback on many features of their essays, as in the case of Criterion (Attali and Burstein, 2006) and MY Access (Elliott, 2003). Criterion scores essays on six areas related to word- and sentence-level analysis that are aligned with human scoring criteria: errors in grammar, errors in word usage, errors in mechanics, style, inclusion of organizational segments (e.g., a thesis statement, some evidence), and vocabulary content.

Intelligent tutoring systems. From 1985 to the present, there have been a number of intelligent tutoring systems developed (see citations above) that track student performance on various tasks, provide feedback, and intelligently guide students in ways that promote learning. The feedback is based on a model of how particular students must have reasoned to act as they did, or alternatively on some mixture of such "model tracing" (what set of mental rules could have produced the student performance details; see Anderson et al., 1995) and reasoning from Bayesian belief networks (Pearl and Russell, 2002). These are networks of the conditional probabilities of having one element of competence given evidence of having or not having others (Conati, Gertner, and VanLehn, 2002; Doignon and Falmagne, 1999).

Instant feedback tailored to the situation. Intelligent tutoring systems operate by trying to discover what pattern of present and missing knowledge best accounts for a student's performance. When considering reading skill training, such systems would model the comprehension skills that a learner exhibits and then provide feedback on text processing that is tai-

lored to the learner's current level of knowledge and skill (Connor et al., 2007). A system might analyze the patterns of reading time allocated to screens of text (Conati and VanLehn, 2000) and diagnose from the processing time patterns that particular kinds of information are not being integrated. Such a system then might have an animated agent suggest to the learner that connections among related ideas be noticed and elaborated. In addition to using the temporal pattern of reading, such systems also could use learner answers to prompt questions to decide which aspects of literacy need further support (see McNamara, 2007b, for a review of such systems).

Detection and tailoring to emotion and engagement level. While the field generally is just beginning to develop, there certainly are examples already of intelligent systems that are sensitive to emotion and, thereby, to motivational state (Baker et al., 2010; D'Mello et al., 2008; Litman and Forbes-Riley, 2006). Such systems can be more flexible in engaging students if they understand when a text is not engaging the student or when a task is producing an emotional response that leads to avoidance rather than deep engagement. Engagement is a central issue in adolescent and adult literacy development, so having tools that can directly gauge emotional state and infer level of engagement should afford opportunities for substantially improved literacy practice tools.

Serious games. Serious games are designed with the explicit goal of helping students learn about important subject-matter content, strategies, and cognitive or social skills. Instead of learning by reading a textbook, listening to a lecture, or interacting with a conventional computer system, the learner plays a game that requires engaging curriculum content and provides learning opportunities as part of the game context. Serious games have revolutionary potential because the learning of difficult content becomes an enjoyable, engaging experience for the learner. Intellectual hard work is transformed into play.

Very few serious games have been around for very long, so some researchers and game developers speculate that game design may be inherently incompatible with pedagogy (Prensky, 2000). The more optimistic view is that there needs to be careful analysis of how the features of games are systematically aligned with the features of pedagogy and curriculum (Gee, 2004b; Gredler, 1996; O'Neil, Wainess, and Baker, 2005; Rieber, 1996; Shaffer, 2007; Van Eck, 2007). Van Eck (2007) has explored how Gagne's principles of instructional design (Gagne et al., 2005) are mapped onto particular features of games. O'Neil, Wainess, and Baker (2005) have presented a similar mapping of game features to Kirkpatrick's (1994) four levels of evaluating training (student reaction, learning, behavioral transfer, and systemic results) and to Baker and Mayer's (1999) model of learning that has five major families of cognitive demands (content understanding,

problem solving, self-regulation, communication, and collaborative teamwork). Ideally, serious games should increase enjoyment, topic interest, and what Csikszentmihaly (1990) calls the flow experience (such intense concentration that time and fatigue disappear). Engagement in the game should facilitate learning by increasing time on task, motivation, and self-regulated activities, as long as the focus is on the instructional curriculum rather than nongermane game components that distract from the knowledge and skills to be learned.

The design, development, and testing of serious games are not grounded in a rich empirical literature, but that is changing. Available reviews and meta-analyses show mixed support as to whether serious games enhance learning of content, strategies, or skills (Fletcher and Tobias, 2007; O'Neil, Wainess, and Baker, 2005; Randel et al., 1992). There are documented success cases that show the promise of serious games, such as Gopher, Weil, and Bareket's (1994) transfer of the Space Fortress game to piloting real aircraft, Green and Bavelier's (2003) transfer of action digital games to visual selective attention, Moreno and Mayer's (2004) use of experimenter-constructed games to train explanations of scientific mechanisms, and a demonstration that mathematics games can promote mathematics achievement and possibly motivation to study mathematics (Kebritchi, Hirumi, and Bai, 2010). Researchers have identified a long list of features that are good candidates for explaining why games enhance motivation (Loftus and Loftus, 1983; Malone and Lepper, 1987; Ritterfeld, Cody, and Vorderer, 2008): interest, fantasy, challenge, play, feedback, narrative, hypothetical worlds, entertainment, and so on. These hooks optimize time on task and so could be useful to learning of reading components. The integration of game components and literacy instruction seems destined to have a large future (Gee, 2007; McNamara, Jackson, and Graesser, 2010).

One important characteristic of rich gaming environments is that they allow for embedding assessment into the learning context. Shute has referred to this as "stealth assessment" because no performance is marked specifically as testing; rather, all action is simply part of the flow of a game (Shute et al., 2009). The basic approach, derived from Mislevy's concept of evidence-centered design (Mislevy, Steinberg, and Almond, 2003), is to build both assessment and instructional choices based on that assessment into the infrastructure behind a learning game. Although research on serious gaming is mostly at a demonstration stage (see National Research Council [2011] *Learning Science Through Computer Games and Simulations*), the approach is strongly anchored in well-proven theory and thus promising for further research, development, and efficacy testing.

Immersion environments. An interesting example of the sophisticated level of intelligent training environments is the system called Tactical Iraqi (Johnson and Beal, 2005; Johnson and Valente, 2008; Losh, 2005), which

has been expanded to a more general Tactical Language and Culture System for multiple languages. This system has intelligent tutoring system components embedded in virtual reality with multiple fully embodied animated agents. This system was developed to help junior officers prepare for duty in Iraq, where they would need to interact with local tribal leaders in a new language and culture. The learners in this system are confronted with realistic situations, such as having to negotiate movement of a medical clinic to ensure that it is not damaged during needed military maneuvers. They then interact with graphically rendered actors, such as village elders, young firebrands who believe all Americans are bad, and others, attempting to achieve the desired goal of moving the clinic. The system is highly engaging, presumably in part because the responses to learners' actions are both cognitive and emotional.

It is not yet clear that this level of realism is needed to engage adult and adolescent literacy learners or which learners would benefit most, but the mere fact that it is possible sets the stage for a range of research that examines what level of intelligent technology is cost-effective for enhancing effective literacy practice. Moreover, as the techniques used in Tactical Iraqi penetrate the electronic games industry and the marketing world, costs may drop enough to make the approach feasible for low-budget adult literacy programming.

Electronic entertainment technologies and related tools. While systems like Tactical Iraqi are expensive in the economic context of adult education, it may be possible to get similar levels of effect from various kinds of entertainment tools, like role playing environments and social media. These range from simple games to rather elaborate possibilities, such as Second Life. The committee encourages both funding agencies and public-private partnerships to explore possible uses. Even if the approaches add little content to what can be done other ways, the motivational value of immersion environments is substantial, and motivation and engagement remain a critical barrier to progress in literacy for adult learners.

A variety of simple tools have been used (mainly in elementary education, some for secondary education, and very little for adult literacy) to help people practice and become more facile in basic components of literacy. The tools promote, for example, practice of basic word reading and increases in vocabulary (see Breznitz, 2006; Lyytinen et al., 2007; Scientific Learning Corporation, 2010; see also the section above on Embedding Low-Level Coaching in Electronic Texts).

Environments, such as Second Life, have quickly engaged significant portions of the adult and adolescent worlds. Their motivational value can be seen in the willingness of participants to pay real money to gain virtual resources, such as clothing, housing, etc., that exist only in the imaginary world on the screen. This level of motivational power might be extremely helpful in stimulating greater levels of literacy activity. Even in the simplest form, one could imagine students writing and revising essays in order to earn virtual clothes for an avatar or access for their avatar to a new environment.

Finally, there is a range of new social media (Second Life is partly a social medium, too), including Facebook, MySpace, and others, that generate large amounts of multimedia communication and might be useful in two ways. One is that, because they are stimuli for large amounts of verbal communication, they may provide a portion of the practice that adults need to build adequate literacy skills. It also is possible, of course, that they instead reinforce activity that never requires deeper comprehension or composition practice. This raises a second possibility, which is that social media might be shaped to require or provide incentives for more productive literacy practice. To some extent, this already may be occurring. For example, increasing numbers of adults are meeting and becoming paired through social media, which places a premium on being able to describe oneself in text and to respond to written questions. More directly, researchers have begun to design and implement social networking sites specifically to support and encourage literacy-rich educational activities for youth, such as multimodal composing, language learning, and intercultural understanding (e.g., Hull, Stornaiuolo, and Sahni, 2010). The committee thinks that this second possibility merits consideration and suggests that such approaches be included among those encouraged in funding for prototype development and validation.

Finally, the Internet, Web 2.0 technologies, and learning systems supported by technology can potentially eliminate or ameliorate constraints of space and time that have traditionally governed adults' opportunities to learn. Given web-based or agent-based tutors and the range of social and cognitive supports that can be provided online, the necessity for adults to be physically present in classrooms at designated times may be greatly lessened. We are not advocating that online tutoring, technologically mediated instruction, or distance education replace face-to-face instruction. However, we think it is important to explore what combinations of physically copresent, Internet-enabled, and computer-supported activity may be effective for adult learners. Because many of these adults must balance the need to extend their literacy learning with the considerable demands and responsibilities of work and family, highly motivating environments may be especially important in stimulating literacy practice.

It is worthwhile to consider promising technologies for adult literacy education even if current development costs are high. Initial versions of instructional software can be very expensive because of the steep learning curve, but the cost becomes much lower with subsequent versions. For example, the first version of one industrial training technology that went through five generations of development cost almost $2 million, but the cost for the fifth version was only $70,000 (Lesgold, in press). Moreover, first-generation development costs for many of the instructional approaches likely to benefit adult literacy learners may be borne by early adopters, such as the military.

SUMMARY AND DIRECTIONS FOR RESEARCH

Technologies with potential to support higher levels of adult and adolescent literacy development are appearing, changing, improving, and becoming more affordable at a very rapid pace. Technologies are vital to making the entire population literate because of their value for improving, leveraging, and making more affordable activities that require intense human effort, such as literacy instruction. Internet technologies also have the potential to alleviate barriers associated with limited times and places of instruction. Digital technologies are important to incorporate into literacy instruction as the tools required for literacy in a digital age.

Ten classes of technologies for learning are potentially available to support the literacy development of those outside K-12 schools: conventionally computer-based training, multimedia, interactive simulation, hypertext and hypermedia, intelligent tutoring systems, inquiry-based information retrieval, animated pedagogical agents, virtual environments with agents, serious games, and computer-supported collaborative learning. These computer technologies would be expected to improve learning because they enable instruction to be adapted to the needs of individual learners, give the learner control over the learning experience, better engage the learner, and have the potential to develop skills efficiently along several dimensions.

Numerous digital tools are potentially available to support adults in practicing their literacy skills and for giving the feedback that supports learning, among them group collaborative communication software, word processing, speech-to-text and text-to-speech tools, embedded low-level coaching of electronic texts, immersion environments, intelligent tutoring systems, serious games, and automatic essay scoring. Studies are needed to establish that the efficacy of effective instructional approaches can be enhanced by technology and to clarify which subpopulations of learners benefit from the technology. Some of this research is emerging with technologies for instruction, with intelligent tutoring systems among those with the strongest positive effects.

The ways in which adults will benefit from instructional technologies will depend on the subpopulation of adults. Given the technologies that are ready to be developed, studies are needed to develop and assess the effects of technologies for English language learners, adolescents and adults with less than high school levels of literacy, learners with disabilities, and college

students who need to enhance their reading and writing skills. In doing the research, it will be important to understand the technology skill sets of both those who need to develop their literacy and the instructors involved in technology-facilitated instruction and to provide the needed supports.

Technology changes quickly in price, availability, and social penetration, making it extremely difficult to know which people are using which technologies at a particular point in time. For example, some may communicate largely through text messaging, and others use social networking sites or business mail systems. To help develop the capacity to use technologies for learning, it will be important to identify both the texts and tools already routinely used by various subgroups of the adult learner population and the types of texts they need to be able to produce and comprehend.

A challenge in the use of technology for adult literacy instruction may be overcoming complex institutional arrangements often involved in changing educational practice. This complexity leads to high institutional inertia in the adoption of technologies that much more rapidly penetrate the general world of consumers. A further challenge is the learning curve for any new technology, during which initial costs are high and utility is not fully developed. Understanding whether a particular technology is worth the investment will require a sophisticated research funding strategy. Such a strategy would involve deciding on the best bets for investment, sustaining the investment long enough for the technologies and their implementation to be refined sufficiently to have substantial impact, and maintaining agility in technology investment and implementation to respond to rapid evolutions in technology.

Research is needed to test new and evolving technologies and resolve inconclusive findings. Many specific uses of technology for adolescent and adult literacy instruction have been shown to be effective in small-scale, controlled studies. For these uses, the next step will be to evaluate them in studies with larger populations and diverse settings. At least as important, though, is programmatic translational research that can show the ways in which an existing instructional system or organization can benefit from the technologies that show the greatest promise.

The National Academies of Sciences, Engineering, and Medicine
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