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EDUCATIONAL TECHNOLOGIES AND LITERACY DEVELOPMENT

Scott A. Crossley and Danielle S. McNamara

Introduction

The purpose of this handbook is to provide actionable information to educators, administrators, and researchers about current, available research-based educational technologies that provide adaptive (personalized) instruction to students on literacy, including reading comprehension and writing. This handbook is comprised of chapters by leading researchers who have developed educational technologies for use in the classroom. Each major chapter in this handbook introduces a currently available educational technology that focuses on the instruction of reading comprehension or writing literacies. The final chapters in this handbook are shorter and introduce technologies that are currently under development.

Educational technologies, such as intelligent tutoring systems (ITS), automated writing evaluation (AWE) systems, and text readability tools, have the potential to fundamentally augment and enhance literacy education. However, many of these technologies remain unused in the contemporary classroom even though numerous studies have indicated their strengths in enhancing learning across a variety of student populations. There are a number of potential reasons such technologies are not found in the classroom, ranging from hesitancy on the part of teachers and administrators to adopt technologies, lack of technology support, and a potential digital divide between teachers, administrators, and students. However, another possible cause stems from a lack of adequate information provided to educators about available technologies for the classroom. Educators do not have easily accessible information about technologies that are potentially usable in their classrooms. A primary reason for this is that researchers generally disseminate such information in academic journals and conference proceedings, which are not readily available to teachers and administrators. Information about

technologies is dispersed, rendering it difficult and time consuming to discover whether the right technology exists and to consider a technology's potential usability in schools. Perhaps most importantly, research articles are often not targeted to the education practitioner and are thus often inaccessible. The purpose of this handbook is to help bridge this divide between teachers, administrators, and educational technology researchers focusing on the development of literacy skills in students of all ages.

Thus, the goal of this book is to provide teachers and administrators with a resource that reviews available educational technologies that have empirical data to demonstrate their success and benefits and provides teachers and administrators with a means to access these technologies. That these available educational technologies focus specifically on reading comprehension and writing, is not unintentional. The recent focus on the common core in the United States renders literacy increasingly important to a wide range of teachers, including those who traditionally focus on literacy such as English Language Arts teachers, but also those who teach content areas such as history and science.

The technologies described in this volume provide evidence that teachers and administrators can facilitate and enhance literacy instruction using adaptive, personalized techniques on a large scale that is only possible with the use of advanced technology. While there are a burgeoning number of educational technologies, there are still too few. We believe that this volume is particularly timely, because there is an increasing number of adaptive reading and writing educational technologies. Our hope is that providing information about available technologies to educators will bolster wider use of these technologies and stimulate the development and dissemination of newer and better literacy technologies for the future.

The following two sections discuss the importance of literacy and describe the need for educational technologies to support literacy. We then briefly describe the chapters and the educational technologies in this volume.

Literacy Skills

Literacy is an important component not only of educational success but also success in business and in life (Geiser & Studley, 2001; Powell, 2009). However, literacy is not acquired quickly. Becoming literate is a long, complex, and difficult undertaking that requires the coordination of a number of cognitive and knowledge skills (National Assessment of Educational Progress, 2011). Importantly, as text becomes more common in e-mails, text messages, and social media posts, the need for strong literacy skills will continue to increase (Barton & Lee, 2013; National Assessment Governing Board, 2011; National Writing Project, 2010).

However, national and international assessments indicate that students struggle to develop strong literacy skills in core areas, such as reading and writing (Carnegie Council on Advancing Adolescent Literacy, 2010). For instance, 25 percent or more of students in the 8th and 12th grades in the United States

perform below a basic level of reading comprehension (U.S. Department of Education, 2011). Importantly, those students who fail to achieve proficiency in basic literacy skills have an increased risk of being referred to special education classes, missing grade level advancements, and dropping out of school (Reynolds & Ou, 2004; Shonkoff & Phillips, 2000).

Problems in literacy within the United States are compounded by the number of English language learners (ELLs) enrolled in public schools (National Clearinghouse for Language Acquisition, 2011). By definition, these students are developing English skills and typically read and write at lower levels than native speakers. The lower-level writing skills of ELL's are evidenced in national test scores in the United States. For instance, as of 2009, Hispanic non-ELL 4th grade students scored, on average, 29 points higher on standardized reading tests than Hispanic ELL students. Hispanic non-ELL 8th grade students scored, on average, 39 points higher on standardized reading tests than Hispanic ELL students. Regrettably, the 2009 statistics for 4th and 8th grade students are not statistically different from the statistics collected in 1998 or 2007, indicating that reading proficiency levels of ELL students are neither increasing nor declining.

Literacy problems in public schools in the United States continue long after students graduate or drop out of school. For instance, studies investigating adult literacy at the international level demonstrate that adults in the United States score below international levels of print and math literacy as well as analytic skills in technological environments (Goodman, Finnegan, Mohadjer, Krenzke, & Hogan, 2013). These literacy problems lead to expenditures for adult literacy programs that serve almost two million students in the United States (Graesser et al., this volume).

The Need for Supplemental Literacy Instruction

The national and international statistics on literacy are not promising. Currently, most students struggle to attain proficient levels of literacy, and teachers do not have enough classroom time or resources to dedicate adequate time to each individual student. Hence, many students still struggle to read at basic levels. Such difficulties may stem from a lack of necessary skills or the knowledge needed to gain a deep understanding of the content embedded within texts (O'Reilly & McNamara, 2007).

From a reading perspective, there is a lack of reading comprehension instruction in elementary classrooms (e.g. Ness, 2011; Pressley, Wharton-McDonald, Mistretta-Hampston, & Echevarria, 1998; Taylor, Pearson, Clark, & Walpole, 2000). A possible explanation for this absence may be that many teachers do not understand the active reading components that are the critical foundation of reading comprehension and many do not appear to be adequately prepared to undertake this challenging task (Pressley, 2006). Furthermore, the teaching of reading literacy strategies is complicated by the explicitness of instruction and the challenge of finding appropriated texts and comprehension questions that

fit the huge variety of task-oriented reading activities that people accomplish in ordinary life (White, Chen, & Forsyth, 2010).

From a writing perspective, research also indicates that many teachers are not adequately trained in writing instruction through either pre- or in-service preparation and, as a result, often do not implement evidence-based writing interventions. This may be because, like reading skills, writing is a complex skill that relies on self-regulation, social awareness of writing purposes, idea generation, knowledge telling, linguistic abilities, and knowledge of the writing process, writing genres, and writing strategies (Flower & Hayes, 1981; Harris & Graham, 2009; Kellogg & Whiteford, 2009).

Of course, reading and writing are intricately linked and both are essential for success in school. For instance, writing about material read or presented in class enhances students' learning of both the subject matter and literacy skills in general (Bangert-Drowns, Hurley, & Wilkinson, 2004; Graham & Hebert, 2010). There is also overlap between the types of effective, evidence-based instruction used in both reading and writing pedagogy. This instruction includes deliberate practice, individualized feedback, and strategy instruction. In terms of deliberate practice, research strongly supports the notion that proficiency in reading and writing is promoted though practice that is purposeful and persistent, allowing students opportunities to read and write text across multiple domains and genres (Duke & Pearson, 2002; Graham & Harris, 2013; Kellogg & Raulerson, 2007; Snow, Burns, & Griffin, 1998). Research indicates that practice is not just helpful; it is necessary for literacy acquisition (Ericsson, Krampe, & Tesch-Römer, 1993; Johnstone, Ashbaugh, & Warfield, 2002; Kellogg & Raulerson, 2007).

However, deliberate practice alone will not lead to proficient literacy. Previous research suggests that the best method for developing overall literacy skills is for students to practice reading and writing in a purposeful manner and in a manner in which they simultaneously receive formative feedback. While formative feedback is important, it is also crucial that the feedback students receive is individualized (Graham & Harris, 2013; Kellogg & Raulerson, 2007). Such feedback can help support writing quality through multiple rounds of revision (Graham & Harris, 2013) as well as motivate students through the revision process (Beach & Friedrich, 2006; Ferris, 2003).

In addition to deliberate practice and formative feedback, best practices in literacy instruction also include strategy instruction. Strategies are effortful and purposeful procedures that are enacted in order to achieve a goal or accomplish a task (Alexander, Graham, & Harris, 1998; Healy, Schneider, & Bourne, 2012). Strategy instruction helps students learn by providing them with concrete information and heuristics (Alexander et al., 1998) that allow them to break up complex tasks into more manageable pieces (Healy et al., 2012). The use of strategies can help students coordinate the different aspects of reading and/or writing a text (Elliot & Klobucar, 2013). Thus, better readers employ a greater number of reading strategies, such as self explaining texts (McNamara, 2004;

O'Reilly, Taylor, & McNamara, 2006), and better writers are better at successfully using strategies during complex writing tasks (McCutchen, 2006). Thus, to improve students' literacy skills, it is critical that students are taught the components of the reading and writing processes as well as strategies that can help them to engage in these processes. Strategies can also help lower-level learners overcome skill deficits in vocabulary or domain knowledge, both of which are important components of literacy (Graham, Harris, & Mason, 2005).

Of course, none of these educational practices operate in isolation; rather, they are dependent on one another to maximize learning. Thus, in order to cement newly learned strategies, students need to be provided with opportunities for sustained and deliberate writing practice (Kellogg, 2008), which can help them understand how and when to use strategies appropriately (Plant, Ericsson, Hill, & Asberg, 2005). At the same time, students should receive individualized feedback to help them to select when to use learned strategies more effectively and appropriately (Shute, 2008). Thus, sustained and deliberate practice combined with individualized feedback help students to develop effective strategies, because practice and feedback allow strategies to be used in practical settings, which staves off strategy forgetting or misapplication (Rohrer & Pashler, 2010).

Overview of Chapters

The purpose of this volume is to provide educators with information about and access to educational technologies for literacy. However effective these technologies might be, we also fully recognize that implementing technology in the classroom is not an easy task. So, we begin with a chapter (Johnson, Jacovina, Russell, & Soto) that discusses these challenges and offers some potential solutions. While there has been some increase in levels of support for technology, teachers often report that the smooth and effective integration of new educational technologies remains challenging. These challenges range from the acquisition of equipment, the adaptation of curricula and teaching techniques to incorporate new educational tools, software training, technical, administrative, and peer support, as well as teacher attitudes, beliefs, and skills. Johnson and colleagues provide a number of suggestions to help integrate technology, all of which revolve around the need for collaborative efforts among teachers, educational technology professionals, school administrators, researchers, and educational software personnel.

The remaining chapters in this volume describe educational technologies that provide adaptive instruction for understanding text or writing. Each chapter provides a description of the technology, why it is needed, who will benefit from using the technology, and evidence for its effectiveness. Importantly, the authors also provide information on how to access each system. These chapters comprise three major parts. The first part describes educational technologies that focus on providing adaptive instruction in reading text and comprehending text at deeper levels. The second part comprises chapters describing technologies for writing.

These technologies provide students with deliberate practice, individualized feedback, and strategy instruction to improve writing quality. The third part describes educational technologies that are representative of our future. In the future, we expect to see a proliferation of writing and reading technologies that actively engage the learner. These short overviews provide a glimpse of upcoming technologies that will be available for classroom use in future years.

Part I: Reading

The first part of this volume focuses on adaptive technologies for reading. The majority of current literacy technologies focus on providing adaptive instruction to the student. By contrast, the first two chapters in this part focus on providing direct support to teachers. Chapter 3 (Ingebrand & Connor) describes A2i, a digital platform that provides K-3 teachers with information about the types and amount of reading instruction needed by developing readers, allowing teachers to more effectively individualize reading instruction for students. The system does so by monitoring student progress across the school year, and suggesting groups of students who need similar types of instruction, such as code focused (e.g., word decoding) or meaning focused (e.g., comprehension) instruction.

Chapter 4 (Jackson, Allen, & McNamara) describes a tool that provides teachers with information about the difficulty of texts read by students. Text difficulty is often described solely in terms of the challenges posed by the words and the sentences. By contrast, the tool for Text Ease and Readability Assessor (TERA) provides a profile of text difficulty encompassing multiple dimensions, including: *narrativity (genre)*, *syntax*, *word concreteness*, *referential cohesion*, and *deep cohesion*. Jackson and colleagues describe these dimensions and provide recommendations to teachers on student needs and instructional approaches that align with these dimensions.

Chapters 5 through 8 describe technologies that provide adaptive reading instruction to students. The first level of instruction is toward learning vocabulary. Indeed, there are several available educational technologies that provide students with practice and feedback on learning new vocabulary. We include Chapter 5 as a representative technology and one of the newest technologies that focus on word learning. DSCoVAR (Dynamic Support of Contextual Vocabulary Acquisition for Reading: Frishkoff, Collins-Thompson, Nam, Hodges, & Crossley) is appropriate for intermediate readers (adolescents to adults), presenting challenging words in various contexts and providing individualized feedback to promote robust word learning.

Chapter 6 describes Intelligent Tutoring of the Structure Strategy (ITSS: Meyer & Wijekumar). ITSS provides students in grades 4–8 with instruction to understand text structure (e.g., comparison, description, cause, and effect) and then to use that structure to comprehend and describe information depicted in expository and persuasive texts.

While ITSS is appropriate for young readers who are learning how to recognize important cues in non-fiction text, generating connections among ideas in the text and with background knowledge becomes increasingly important for developing readers. Chapter 7 describes Interactive Strategy Training for Active Reading and Thinking (iSTART), a technology that focuses on providing students in grades 7–14 with comprehension strategies that promote effective inferencing. iSTART-2 (Snow, Jacovina, Jackson, & McNamara) is a game-based educational technology designed to improve students' comprehension skills by providing them with instruction on how to self-explain text using comprehension strategies, such as paraphrasing and making bridging inferences. The system is designed for students in middle school, high school, and college and has been shown to improve students' reading comprehension skills, particularly for complex texts.

Recognizing the importance of developing technologies for ELLs, the developers of ITSS and iSTART have also created versions of their tutoring technologies for Spanish speaking learners. Chapter 8 (Vidal-Abarca, Serrano, Ramos, Gil, & Ferrer) describes TuinLEC, an educational technology designed specifically for Spanish speaking students at the upper elementary level. TuinLEC focuses on teaching students strategies to answer multiple-choice questions that are typical of standardized assessments. Students learn to develop a better understanding of the text before answering questions, and when to refer back to the text when it is available.

Part II: Writing

The second part of the book contains chapters that focus on providing students with deliberate practice, individualized feedback, and strategy instruction for writing. Systems that provide students with deliberate practice and language specific feedback for writing are commonly found in the commercial sector. The sheer number of these systems precludes an individual chapter for each system. Hence, Chapter 9 (Allen & Perret) provides an overview of many of the available systems. All of the systems vary in their specific properties, but commonalities include automated essay scoring (AES) engines to assign scores to essays and AWE systems to provide students with some form of feedback on their writing. This feedback can range from the detection of lower-level spelling and grammar errors to higher-level components related to rhetorical language use. Chapter 10 provides a detailed account of the earliest and best known of commercialized systems, *Criterion*® (Ramineni & Deane). *Criterion*® Online Writing Evaluation Service is a writing tool that affords the collection of writing samples, scoring of those writing samples, and immediate feedback to the writer through the *e-rater*® AES engine (Burstein, Tetreault, & Madnani, 2013).

The following two chapters in the writing section move beyond only essay quality and feedback and provide students with writing strategy training. Chapter 11 provides an overview of We-Write (Wijekumar, Harris, Graham, & Myer). We-Write

modules include teacher-led and computer supported modeling, practice tasks, assessment, feedback, and scaffolding. The focus of We-Write is on self-regulated strategies development, which helps students in grades 4–5 plan, draft, revise, and reflect on persuasive writing tasks.

Chapter 12 describes the Writing-Pal (W-Pal; Crossley, Allen, & McNamara). W-Pal targets adolescent writers, but can be used effectively from middle school to first-year college classes. W-Pal is an automated tutoring system that provides instruction on writing strategies through lessons, game-based practice on these strategies, essay writing practice, automated essay scoring, and practical feedback for essay revision.

Chapter 13 (Cotos) focuses on a technology that helps advanced students develop and write research articles. The *Research Writing Tutor* (RWT) employs the conventions of scientific argumentation to facilitate the learning of scientific writing conventions. RWT also provides rhetorical feedback to writers to help them engage in interactive writing to promote meaningful text revision.

Chapter 14 describes SWoRD (recently renamed Peerceptiv; Schunn), a system designed to support peer review of essays for high school and college students. Like *Criterion*® and RWT, SWoRD provides students with feedback on their writing, but, uniquely, this system provides an automated approach for effective peer review. The objective of the system is to harness the power of peer reviewing to produce accurate ratings of essay quality and useful feedback for writing improvement.

Part III: Future Technologies

The last part of the volume focuses on educational technologies for literacy that are under development. These chapters are short overviews that provide a glimpse of upcoming technologies that will soon be available for classroom use. Chapter 15 describes Project Listen (Mostow), an educational tool that improves reading fluency by reading along and providing feedback to young children in grades 1–3. Chapter 16 introduces EMBRACE (Glenberg, Walker, & Restrepo), which is designed to improve both general and STEM reading comprehension for young ELLs (grades 2–5). Chapter 17 provides an overview of PALETTE (Burstein & Sabatini), a tool that can automatically generate activities for middle school ELLs to support students' language development and content comprehension. Chapter 18 introduces RSAT (Magliano, Ray, & Millis), which provides teachers with direct evaluations of what students do as they read. Chapter 19 discusses an iteration of the AutoTutor ITS that provides reading strategy instruction for adult literacy learners (Graesser et al., this volume). Fittingly, our final chapter focuses on a system that merges both reading and writing instruction, Udio (Boucher, Evans, & Graham). Udio provides students with a wide variety of high-interest and age-relevant readings along with opportunities to write projects in support of these readings.

Conclusions

As discussed in multiple chapters throughout this book, providing students with deliberate practice, individualized feedback, and strategy training is difficult to accomplish in the classroom, because of time constraints and class sizes. Literacy skills are only one of many skills taught in the classroom and finding time to allot to deliberate and guided practice is difficult. In addition, with larger class sizes, teachers do not have the time to read and process large quantities of student text (National Commission on Writing, 2004). This is especially true for writing assignments for which it is more time consuming to review each student's writing and give individualized, formative feedback (Grimes & Warschauer, 2010; Roscoe, Varner, Snow, & McNamara, 2014).

Fortunately, educational technologies, such as those described in this volume, can provide supplemental instruction to help teachers address restrictions that result from large class sizes and limited classroom time. In fact, the expressed purpose of these educational technologies is to afford students opportunities for deliberative practice in reading and/or writing. In many cases, the technologies can also provide individualized feedback to the learner, and many of the educational technologies contained in this book can help students develop better literacy strategies to help them independently increase their reading and writing proficiency.

The educational technologies described within this volume offer exciting opportunities for supplemental classroom activities to support increased literacy skills. Importantly, the technologies provide students with opportunities for deliberate practice, individualized feedback, and strategy instruction, all hallmarks of efficient literacy instruction. In addition, and perhaps most importantly, these technologies lead to learning gains for students in terms of reading comprehension and writing proficiency. In sum, the technologies work.

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