Hammill Institute on Disabilities

Remedial and Special Education
33(3) 162–172

DOI: 10.1177/0741932510381651
http://rase.sagepub.com
SAGE

Literacy by Design: A Universal Design for Learning Approach for Students With Significant Intellectual Disabilities

Peggy Coyne[1], Bart Pisha[1], Bridget Dalton[2], Lucille A. Zeph[3], and Nancy Cook Smith[4]

Abstract

Literacy instruction for students with significant intellectual disabilities traditionally emphasizes isolated skills instruction focusing on sight words and basic vocabulary. Recent research suggests these students benefit from high-quality instruction that includes comprehension and storybook reading. This study examined the effect of a technology-based universal design for learning (UDL) approach to literacy instruction, Literacy by Design (LBD), on the reading achievement of 16 students with significant intellectual disabilities in Grades K–2. The LBD approach emphasizes reading for meaning, combining UDL-scaffolded e-books and letter and word recognition software. Nine teachers received training in research-based literacy practices. Of these, five received LBD training and implemented it four to five times weekly. Controlling for initial reading achievement, the LBD group made significantly greater gains on the *Woodcock–Johnson Test of Achievement III* Passage Comprehension subtest. Implications for research and practice in beginning reading instruction for children with significant intellectual disabilities are discussed.

Keywords

literacy, mental retardation, universal design for learning, technology

The reauthorization of the Individuals With Disabilities Education Act (1997, 2004) and the passage of No Child Left Behind (2002) signaled a more expansive and potentially liberating view of literacy and learning for students with significant intellectual disabilities—one that would promote participation and progress in the general education curriculum (Jackson, 2005). As the report of the President's Commission on Excellence in Special Education (PCESE, 2002) states, "Leaving no child behind . . . means leaving no children with disabilities behind" (p. 42).

Achieving the goal of improved literacy achievement for students with significant intellectual disabilities has remained elusive. Despite the critical role of literacy in the curriculum, many students with significant intellectual disabilities have limited opportunities for effective literacy acquisition because of the poor quality or absence of literacy instruction, often combined with educators' low academic expectations (Erickson, Hanser, Hatch, & Sanders, 2009; Katims, 2000; Kliewer & Biklen, 2001). For the current study, we developed and field tested the Literacy by Design (LBD) instructional approach and accompanying multimedia e-books to learn whether young students with significant intellectual disabilities would benefit from a technology-based universal design for learning (UDL) approach to literacy instruction. The e-books embed supports in each of the five areas of instruction identified by the National Reading Panel (NRP, 2000) report as critical for successful, balanced literacy instruction: phonemic awareness, phonics, vocabulary, fluency, and comprehension.

Traditional Instruction for Students With Significant Intellectual Disabilities

Literacy instruction for students with significant intellectual disabilities has traditionally focused on drill and practice instruction of sight words and other basic literacy skills in isolated contexts (Erickson & Koppenhaver, 1995; Katims, 2000), with little consideration given to balanced literacy instruction (Al Otaiba & Hosp, 2004). Attention to more difficult and complex literacy tasks is lacking (McLaughlin, 1999), with

[1]CAST, Wakefield, MA, USA
[2]Vanderbilt University, Nashville, TN, USA
[3]University of Maine, Orono, ME, USA
[4]Harvard-Smithsonian Center for Astrophysics, Cambridge, MA, USA

Corresponding Author:
Peggy Coyne, CAST, 40 Harvard Mills Square, Suite 3, Wakefield, MA 01881
Email: pcoyne@cast.org

limited focus on reading for meaning, a core process, and literacy outcome. As a result, students with significant intellectual disabilities fall increasingly behind in literacy (PCESE, 2002).

This narrow focus in literacy instruction is in part because of the gap in our knowledge base on effective reading instruction for individuals with significant intellectual disabilities, with much of the research focusing on word recognition and functional literacy. Al Otaiba and Hosp's (2004) review of the literature revealed several studies on effective instruction for sight word retention, phonemic decoding, and phonological awareness and one study that supported the integration of phonics and basal reading instruction. However, they found no studies that investigated fluency, vocabulary, or reading comprehension, indicating the lack of knowledge regarding how to instruct students with significant intellectual disabilities in these more complex areas of literacy.

In a second review, Houston and Torgesen (2004) examined studies of reading instruction for students with moderate intellectual disabilities in relation to the five areas of reading instruction identified by the NRP (2000). They concluded that there is an "absence of clear direction about the exact sequence and methods for teaching these students" (p. 6). However, there was some support for explicit comprehension instruction, especially when oral language and reading comprehension were both addressed. Browder, Wakeman, Spooner, Ahlgrim-Delzell, and Algozzine (2006) similarly applied the NRP (2000) framework to analyze 128 studies on teaching reading to students with moderate to severe intellectual disabilities. This comprehensive analysis revealed that the vast majority of studies examined only one or two areas of literacy instruction and that more than two thirds of the studies examined the teaching of sight words with an emphasis on functional words. Browder et al. found "insufficient studies to glean evidence-based practices for *phonics and phonemic awareness*" (p. 399), and although *fluency* was measured, appropriate teaching methodologies to promote it were rarely described or implemented. Studies related to *vocabulary* instruction represented the largest body of research, but these studies primarily addressed sight word acquisition as an indicator of vocabulary development. Just 31 studies addressed *reading comprehension*, with the majority focusing on comprehension of functional activities and word-to-picture matching. Browder et al. recommended additional research to address the seven other comprehension strategies identified by the NRP, such as story structure, summarizing, and graphic organizers. They concluded that the current body of research informs educators on how to teach sight vocabulary but provides no guidance for other areas of literacy instruction defined by the NRP (2000). Erickson and her colleagues (2009) also identified a lack of research-based practices in these five areas, especially in the area of comprehension.

Promising Approaches in Literacy Instruction for Students With Significant Intellectual Disabilities

Although relatively little research has examined comprehensive reading approaches for students with significant intellectual disabilities, findings suggest that these students can benefit from high-quality, balanced literacy instruction and, in some cases, the same research-based instructional approaches found for typical learners (Browder, Ahlgrim-Delzell, Courtade, Gibbs, & Flowers, 2008; Hedrick, Katims, & Carr, 1999). For example, researchers report that students with significant intellectual disabilities may profit from literacy instruction that focuses on reading for meaning, provides direct instruction in the skills and strategies needed to decode and understand, and uses appealing print in meaningful contexts (Katims, 2000; Mefferd & Pettegrew, 1997). Moreover, like their peers without disabilities, students with significant intellectual disabilities are engaged by reading storybooks and benefit from reading and discussing books with their teachers and peers (Koppenhaver, Coleman, Kalman, & Yoder, 1991; Skotko, Koppenhaver, & Erickson, 2004). Researchers are beginning to apply this new knowledge in the development of comprehensive approaches to literacy for these students (Browder, Gibbs, Ahlgrim-Delzell, Courtade, & Lee, 2007). Programs such as Erickson's (2004) MEville to WEville also integrate technology to provide students with engaging and beneficial learning environments for reading and writing.

UDL

A potentially promising approach to enabling more students with significant intellectual disabilities to gain access to research-based, balanced literacy approaches is through the integration of UDL and technology to create more supportive and accessible learning environments. UDL applies recent advances in the understanding of how the brain processes information to the design of texts and curricula that can be flexible enough to meet individual student needs (Rose & Meyer, 2002). UDL provides a framework for the design of learning environments that scaffold and provide (a) multiple ways to access information and knowledge (the "what" of learning), (b) multiple ways to approach strategic tasks (the "how" of learning), and (c) multiple ways of becoming and staying engaged in learning (the "why" of learning; Meyer & Rose, 1998, 2005; Rose & Meyer, 2002). UDL aims to decrease potential barriers to learning while increasing opportunities to learn. It rests on a belief that designing for diverse learners results in better learning outcomes for all individuals.

Scaffolding is a core feature of UDL. In their seminal work, Wood, Bruner, and Ross (1976) defined scaffolding as being situated within a social context whereby the tutor "enables a child or novice to solve a problem, carry out a task, or achieve a goal that would be beyond his unassisted efforts" (p. 90).

Scaffolding is a balance between obtaining and maintaining a child's engagement, simplifying the task when needed, providing confidence for risk taking, marking relevant information, and demonstrating potential solutions. It plays an important role in literacy development, as teachers consciously provide and withdraw specific supports to maximize student learning. This involves a complex balance among knowledge of a student's learning strengths and weaknesses, knowledge of the curriculum demands, and understanding of the means to successfully challenge and withdraw scaffolds as a student progresses (Almasi, 2003; Berk & Winsler, 1995).

There is a growing body of research on the ways in which technology can be used to provide scaffolds directly within digital text to support reading (for reviews, see MacArthur, Ferretti, Okolo, & Cavalier, 2001; Strangman & Dalton, 2005). Digital text can provide an apprenticeship environment to guide students in actively constructing meaning through modeling and demonstration, reading with feedback and practice, and use of leveled scaffolds that change and gradually fade with increasing student expertise (Cognition and Technology Group at Vanderbilt, 1993; Collins, Brown, & Newman, 1989).

Research on UDL has focused on integrating technology and media with sound instructional strategies and curricula to create customized scaffolded learning experiences for students with diverse needs (Dalton & Proctor, 2007; Pisha & Coyne, 2001; Wehmeyer, Smith, Palmer, Davies, & Stock, 2004). Support for applying UDL principles to the design of digital literacy environments is found in research on e-books with embedded supports for reading comprehension strategies (Dalton, Pisha, Coyne, Eagleton, & Deysher, 2002), reading strategies combined with interactive vocabulary (Proctor, Dalton, & Grisham, 2007; Proctor, Uccelli, Dalton, & Snow, 2009), and reading strategies combined with progress monitoring (Hall & Murray, 2009). However, most of the research to date has been conducted with typically achieving and struggling readers in the middle grades. Adapting the UDL e-book framework for young children with significant intellectual disabilities, Dalton and Coyne (2002) formatively developed an e-book prototype. Students were highly engaged by the e-books and were able to navigate the interface and use the various supports; however, this study did not assess the effect on reading achievement.

To address this gap in theory and research on UDL, the current study investigated the effect of LBD, a universally designed approach to literacy instruction that addresses the five components of balanced literacy recommended by the NRP (2000), on the reading achievement of young students with intellectual disabilities. The guiding research question was, for children in Grades K–2 with significant intellectual disabilities, what effect does a UDL technology-based reading approach (LBD) versus traditional reading instruction have on students' reading comprehension, fluency, phonemic awareness, phonics, and vocabulary development?

Method

Participants

Teachers and setting. Nine teachers of K–2 students with significant intellectual disabilities, in both inclusive and substantially separate classrooms, volunteered to participate in this research. To guide our selection, we visited each school, met with teachers, specialists, and principals, and observed students during class instruction. Since the intervention was designed to influence the class and overall instructional approach, student participation in the intervention was based on teacher assignment. There were five intervention and four control classrooms in five schools located in two New England states. Our assignment was purposeful to balance instructional setting (inclusive and substantially separate classrooms) and location (States 1 and 2). State 1 included two classrooms (one intervention and one control) located in a substantially separate suburban school building and two substantially separate classrooms (one intervention and one control) in an urban elementary school. State 2 included five inclusive classrooms located in five rural elementary schools (three intervention and two control).

Students. Once teachers were identified, 23 student participants were selected based on the school's determination that students met two criteria: (a) they were reported to have demonstrated significantly subaverage intellectual functioning and deficits in two or more adaptive skills areas (Luckasson et al., 1992) and (b) they received reading instruction in one of the identified classrooms. We relied on each school's determination of intellectual level; IQ scores were not available for any of these students. In each case, the examiner indicated in the child's record that it would not be appropriate to administer an IQ test. We did not conduct follow-up testing.

From October to May, we collected complete data sets from 16 students who relied on spoken English for communication. We were not able to obtain baseline scores on the pre-post quantitative measures for the 6 students identified as nonverbal. This article reports on the quantitative findings for the 16 students who were able to communicate verbally. Qualitative case studies of the children who are nonverbal may be found in Dalton, Zeph, Coyne, and Enright (2006).

Of the 16 students, 8 were in the LBD classroom and 8 in the control classroom (see Table 1). One control and one intervention classroom had a single participating student; all other classrooms had 2 or 3 participating students. Students' primary diagnoses in both conditions varied and included multiple disabilities, developmental disability, autism, Prader–Willi syndrome, Down syndrome, Fragile X, and pervasive developmental disability. Many students had various physical disabilities, and the range of communication issues frequently seen in individuals with significant intellectual disabilities was also present.

Table 1. Student Demographics

	Literacy by Design (n = 8)		Control (n = 8)	
Characteristic	*n*	%	*n*	%
Race/ethnicity				
European American	7	87.5	7	87.5
Hispanic	0	0.0	1	12.5
African American	1	12.5	0	0.0
Gender				
Male	5	62.5	6	75.0
Female	3	37.5	2	25.0
Age				
Average	7.1		7.8	
Range	5.10–9.1		6.2–9.9	
Classroom setting				
Inclusive	3	37.5	3	37.5
Separate	3	37.5	1	12.5
Substantially separate	2	25.0	4	50.0

LBD Materials

Drawing on the research-based UDL-thinking reader instructional framework (Dalton & Proctor, 2007) and pilot work with children with intellectual disabilities (Dalton & Coyne, 2002; O'Neill & Dalton, 2002), we developed four universally designed digital story books, including two animal fantasies, one folktale, and one contemporary fiction. The primary focus of these scaffolded e-books was comprehension, while also addressing phonemic awareness, phonics instruction, vocabulary, and fluency. The embedded supports are based on the three principles of UDL, as described in Table 2.

Supports were leveled to provide appropriate levels of challenge and engagement and focused on developing beginning reading skills in context. Figure 1 shows screenshots of the two main activity areas of the LBD e-books, "Read and Understand," which focuses on comprehension and vocabulary, and "Read Aloud," which supports phonics and fluency.

In addition to the LBD e-books, students used two complementary software programs: WiggleWorks (1996) provided a large library of e-books to supplement the LBD e-book inventory, and Island Adventure (1997) and Ocean Adventure (1997) provided a set of interactive exercises and games for teaching phonemic awareness and phonics. The combination of UDL scaffolded e-books, the WiggleWorks e-book library, and letter and word recognition game software provided access to a wide selection of materials that support teaching of the five core reading areas in context (see Table 3).

Measures

At the beginning and end of the academic year we collected pre- and posttest data on 11 quantitative reading and language measures from 16 children with significant intellectual disabilities who were able to communicate verbally. All assessments were individually administered by researchers with testing experience.

We assessed reading growth with the widely used *Woodcock–Johnson Tests of Achievement III* (WJ-III; Woodcock, McGrew, & Mather, 2001), including Letter-Word ID, Understanding Directions, Passage Comprehension, Word Attack, Picture Vocabulary, Oral Comprehension, and Sound Awareness. In addition, we calculated two composite scores, Listening Comprehension (Understanding Directions and Oral Comprehension) and Basic Reading (Letter-Word ID and Word Attack). This measure is a highly regarded and statistically robust standardized assessment of reading achievement that yields interval-level scale scores. In addition, we used two criterion-referenced measures, *Letter Identification*, upper and lowercase (Clay, 2000a), and *Concepts About Print* (Clay, 2000b), to ascertain students' alphabet and book knowledge. Students earn a maximum raw score of 52 for letters recognized and a raw score of 24 for various concepts about print, such as identifying the front cover, pointing to a word within a sentence, and so on. These measures were selected as they address the components of a high-quality instructional approach, such as reading for meaning, vocabulary, and familiarity with book reading.

Training and Classroom Implementation

All teachers, control and intervention, attended an introductory all-day workshop on literacy best practices, including evidence-based strategies for teaching the five areas identified by the NRP (2000), strategies used by proficient readers, instructional practices such as think alouds, and strategies for teaching students with significant intellectual disabilities. The LBD teachers received an additional day of training on how to teach with the three software packages (LBD e-books, Scholastic WiggleWorks e-books, and Riverdeep's Island Adventure and Ocean Adventure). Teachers read and tried out the various instructional supports within the LBD and Scholastic e-books and played the letter-word games to become familiar with the goals and operation of each program. Then they planned for how they could be used pedagogically in their classrooms.

All students in the LBD and control classrooms participated in a 90-min literacy block from October through May. As part of their total literacy program, LBD students received 20 to 30 min per day of context-based reading instruction supported by the intervention software. Each LBD classroom had one desktop computer, one pair of headphones, and one microphone dedicated to the project. Researchers conducted weekly observations of LBD teachers or their teaching assistants during the time they taught LBD students. Technical

Table 2. Universal Design for Learning (UDL) Principles and Literacy by Design (LBD) E-book Features

UDL Principle	LBD E-book Features
Multiple means of representation	Sentence-by-sentence human digitized voice with synchronized highlighting
	Word and phrase synthetic text to speech with synchronized highlighting
	Animation and oral pronunciation of onset-rhyme for phonetically regular words
	Hyperlinked glossary items with graphic and multimedia illustrations
	Story illustration enhancements (e.g., click on a character to hear what the character is thinking and feeling)
	Videos and photo essays to build background information (e.g., hide-and-seek video, photos of a trip to a bakery)
Multiple means of action and expression	Prompts to apply reading comprehension strategies (e.g., predict, question, retell, connect) and personal response (e.g., How is the character feeling?)
	Pedagogical agents that provide prompts, think alouds, and models
	Varied response options (e.g., visual multiple choice, sentence starters, open responses typed or audio-recorded)
	Prompts to echo read, partner read, and read independently guided by pedagogical agents who demonstrate the process
	Student work logs capture all written and audio-recorded responses
Multiple means of engagement	Use of popular children's stories with quality illustrations
	Students are encouraged to decide when to click on a support option and are given control of the mouse so that they are in charge of navigation
	Students are encouraged to choose their response option (typed or audio-recorded)
	Students listen to their oral reading recordings
	Prompts to reflect on progress and identify what they like or don't like
	In addition to teacher-guided reading, students may elect to read stories independently

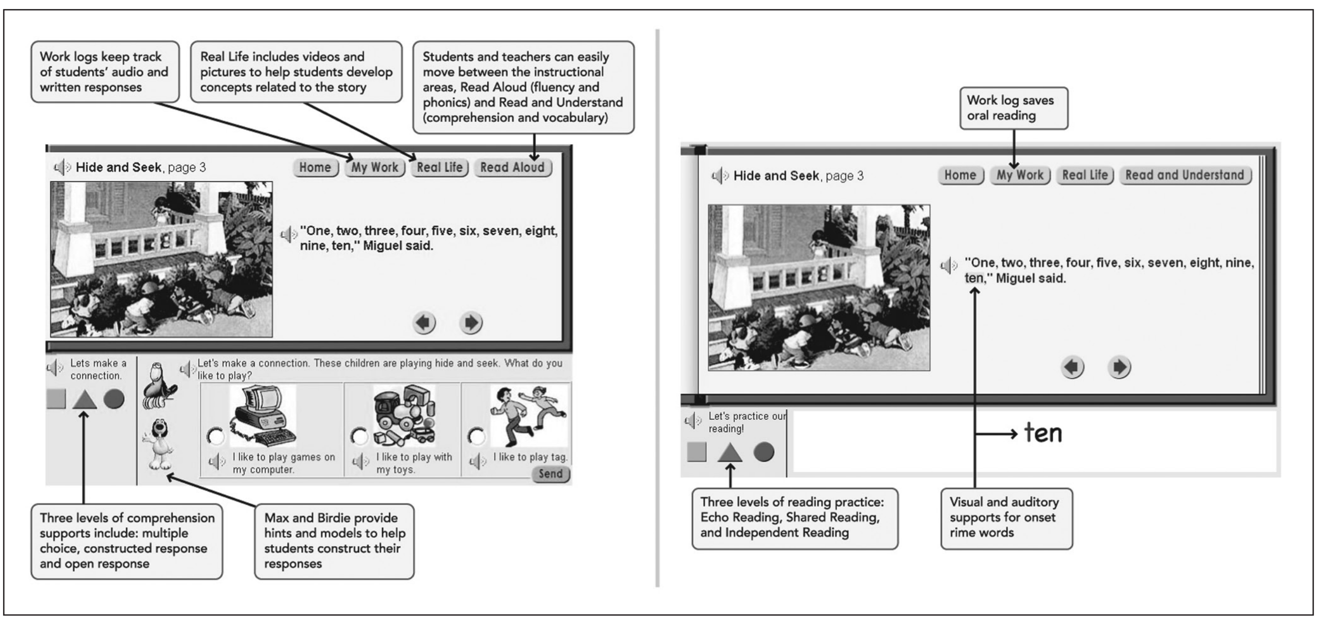

Figure 1. Literacy by Design reading scaffolds. The Read and Understand area focusing on comprehension is depicted on the left. The Read Aloud area focusing on word recognition is on the right. Reprinted with permission of CAST, Inc.

assistance and instructional support were provided as needed. For example, teachers initially needed help with computer troubleshooting (e.g., unfreezing a screen) and expanding their instructional interactions to include the full range of embedded LBD instructional supports (e.g., viewing the "real-world" video to build prior knowledge, varying the mode of student response). They all learned to use the software with a high degree of comfort within several weeks and conveyed during exit interviews their interest in continuing to use the software beyond the end of the study.

Table 3. Software Features That Support Beginning Reading

National Reading Panel (2000) Areas of Reading Instruction	Universal Design for Learning E-books (Researcher Designed)	WiggleWorks E-books (Scholastic)	Island Adventure and Ocean Adventure (Riverdeep)
Phonemic awareness	Specific supports not embedded	Specific supports not embedded	Matching sounds, letter–sounds games
Phonics	"Read & Practice": Click phonetically regular words to animate onset-rhyme and sound out blending; digital voice narration	Digital letter magnet board for combining letters and using word families to create words	Interactive activities and books focused on sound symbol matching, blending
Comprehension	"Read & Understand": Reading strategy prompts with pedagogical agents who provide hints and models; visual multiple choice, type, or audio-record open responses	Writing feature, "My Book," to type or audio-record retelling of story with or without illustrations	Specific supports not embedded
Fluency	"Read and Practice": Prompts to echo-read, partner-read, or read independently; pedagogical agents provide models; audio-record oral reading	WiggleWorks e-books are designed to be listened to and read along with; students may audio-record oral reading	Activities designed to increase word recognition; books provide audio feedback; students audio-record oral reading
Vocabulary	Hyperlinked multimedia glossary, "real-life" videos and photo essays	Specific supports not embedded	Specific supports not embedded

To expand on the LBD instructional experience, a typical session included time reading and interacting with an LBD e-book, a WiggleWorks e-book, and the letter and word recognition software. Teachers and teacher assistants primarily worked one on one with students when using the LBD e-books. Teachers decided which components of the program to use with which students. At the beginning of the intervention, teachers modeled how to use the embedded supports and guided students quite closely. Within 2 to 3 months, students were observed navigating the program and inputting responses independently, with the teacher or assistant sitting by their side at the computer, focusing on expanding the students' responses and making linkages to reading off the computer. As the year progressed, teachers and assistants continued to work one on one with students using the three software programs while also allowing students to read the LBD and WiggleWorks e-books and to play the letter-word recognition games independently. In the inclusive LBD classrooms, the students became the classroom "experts" on the software, often supporting typical peers who wished to use the software. Observations demonstrated students' eagerness to read the storybooks and play games on the computer. Anecdotal reports from teachers often focused on students' engagement with the software while also acknowledging the learning benefit. As one teacher explained, "They're interacting more, they're enjoying it, they're having fun with it. And they're learning from it. They don't realize. . . . They love to use the software and don't realize that they're learning."

The control teachers followed their "business as usual" literacy program. Prior to joining the study, all of the teachers reported that their curriculum and instruction addressed the five areas of reading instruction identified in the NRP report. Control teachers were observed once a month during their literacy block. These observations confirmed that teachers were addressing word-level skills, vocabulary, and comprehension, with some variation as to be expected. Students received instruction individually and in small groups usually including one other student. In the inclusive control sites, students received their instruction in the general education classroom, typically with the support of an educational assistant.

Fidelity of Treatment

During October to May, researchers conducted weekly 45-min observations of the LBD classrooms and monthly observations of the control classrooms during literacy instruction. In addition to field notes, researchers recorded whether or not instruction in each of the five components of reading was observed during the session (this was a yes–no determination; multiple instances were not recorded). For example, in the LBD classrooms, if the student had worked in the Read and Understand section of the LBD e-book, the observer checked *yes* that comprehension was addressed; if the student played a game in Island Ocean Adventure, the instructional focus was phonics or phonemic awareness, depending on the game. Similarly, if control students were working on a vocabulary sheet, the researcher would check *yes* for vocabulary; discussing the meaning of a text would be counted as evidence of comprehension. In the control classrooms, if students were working with a vocabulary worksheet, the observer coded *yes* on vocabulary; if they were discussing a story event, the researcher coded comprehension. On average, 43.8% of the observed LBD sessions included phonemic awareness instruction, 37.5% included phonics, 31.5% included fluency, 45.8% included vocabulary, and 68.5% included comprehension. Observation of the control classrooms indicated that 22.9% of the sessions included phonemic awareness instruction, 44.3% included phonics, 20.8% included fluency, 40.2% included vocabulary, and 38.5% included comprehension. Although both intervention and control classrooms included instruction in each of the reading instruction areas, the largest difference in instructional focus was the greater emphasis on comprehension and phonemic awareness in the LBD classrooms.

During the weekly visits, researchers checked in with the LBD teachers regarding their software use. They self-reported that they were using the software the required four to five times per week. Although asked to complete a daily work log indicating which software they had used, the reports were sporadic. Based on the 233 work logs collected, teachers reported using the LBD storybooks (36.1%), WiggleWorks (42.1%), and Island and Ocean Adventure (24.4%), figures that are consistent with the observations that indicated more use of the software that focused on comprehension instruction.

Analysis

We chose an ANCOVA strategy for the analysis of these data because univariate analysis and administration of Levine's test of students' pretest scores indicated that the mean scores of the intervention and control groups varied from each other on some measures to an extent that might have been sufficient to compromise a traditional ANOVA analysis. The LBD group pretest scores were significantly higher than the control group on the Letter-Word ID, $t(14) = 2.16, p < .05$, and Picture Vocabulary subtests, $t(14) = 2.78, p < .05$. Huck (2000) notes that ANCOVA adjusts each group mean on the dependent variable, thereby minimizing the effect of these differences and providing an appropriate alternative to ANOVA for this analysis.

The dependent variables for these analyses were posttest scores adjusted for pretest scores made by students on each of our 11 quantitative measures. We compared posttest scores of students in the LBD classrooms to posttest scores made by students in the control classrooms where teachers were not provided with LBD materials but continued to teach in their customary ways. Pretests on standardized and nonstandardized measures served as the covariates in these analyses.

We determined that ANCOVA was appropriate for the analysis of these data because there was a statistical control based on individual performance, specifically the pretest scores for each dependent measure. Functionally, the residual for each individual is calculated after a regression analysis predicts all posttest scores on the basis of the degree of covariance between the pretest and posttest scores. The use of ANCOVA helped to minimize the effect of the relatively large variation between individual students' pretest scores and facilitated comparisons between the intervention and the control groups. The dependent variables in all analyses were posttest scores that had been adjusted, via ANCOVA, for pretest variance. Levine's test of equality of variance was employed prior to each ANCOVA to test the critical assumption of inference statistics that the covariates were acceptably homogenous. When the variables were examined using Levine's test, no variable achieved statistical significance at the $p < .05$ level. This indicated that the assumption of homogeneity of covariates was not violated.

Results: Multivariate Analysis of Pre- and Posttest Scores

Table 4 presents pre- and posttest scores and shows the results of ANCOVA analyses of students' scaled scores on the WJ-III subtests and composites and students' raw scores on *Concepts About Print* and *Letter Identification*. The latter instruments do not yield "standardized" scores (i.e., an equal interval level of measurement or consideration of norms with such scores as normal curve equivalent or *z* scores) and are used here as criterion-referenced measures of demonstrated learning.

The differences between adjusted posttest scores of the LBD and control groups were statistically significant (in favor of the LBD group) at the $p = .02$ level on one subtest of the WJ-III, Passage Comprehension. The effect size was 1.44. Other measures that had an effect size nearing or equal to 1 included two subtests on the WJ-III, Word Attack (0.91) and Listening Comprehension (1.00), and *Concepts About Print* (0.92). Effect sizes were calculated by dividing the coefficient for treatment by the root mean square error for the model. This approach allows us to focus on the effect of the treatment, controlling for pretest score.

Discussion

The results of the LBD project add to a small but growing body of research demonstrating the potential value of comprehensive literacy programs for children with significant intellectual disabilities that address five core aspects of literacy—phonemic awareness, phonics, fluency, vocabulary, and comprehension (Erickson et al., 2009). After controlling for initial reading achievement, the LBD group, on average, made significantly higher gains in comprehension than did the control group, suggesting a strong effect of the intervention. Analysis of effect sizes suggests LBD also had a strong effect on students' Word Attack skills, listening comprehension, and *Concepts About Print*. However, these effects should be interpreted with caution, given the small size of the sample.

Although it is not possible to tease out the effects of the various components of the LBD approach, its design rests on

Table 4. Pretest and Posttest Reading and Language Achievement Standard Scores

	Literacy by Design (n = 8)				Control (n = 8)						
	Pretest		Posttest		Pretest		Posttest				
Measure	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*F*	*P*	Effect Size
WJ-III Letter-Word ID[a]	85.1	15.9	81.6	23.1	65.9	19.5	61.0	19.1	0.084	.78	0.17
Understanding Directions	75.3	10.7	75.6	15.2	72.1	12.4	65.3	16.1	1.338	.27	0.58
Passage Comprehension	64.9	46.0	79.9	16.5	43.8	33.6	51.6	20.9	7.649	.02*	1.44
Word Attack	45.9	40.4	76.4	22.3	40.2	44.2	54.2	25.1	3.288	.09	0.91
Picture Vocabulary[a]	92.6	13.3	95.9	12.3	73.0	14.8	82.8	8.1	0.142	.71	0.23
Oral Comprehension	49.8	41.4	80.9	33.2	35.4	39.0	48.5	42.1	2.264	.16	0.77
Sound Awareness	33.0	36.6	50.6	33.0	14.8	27.6	31.9	34.3	0.472	.50	0.36
Listening Comprehension composite	66.8	10.4	77.9	11.0	60.6	12.6	59.6	19.3	3.701	.08	1.00
Basic Reading composite	79.3	15.4	78.4	23.4	65.4	19.5	60.6	15.2	0.667	.42	0.44
Concepts About Print	2.6	1.8	11.0	5.9	2.3	2.5	7.1	4.4	3.327	.09	0.92
Letter Identification	36.5	20.2	45.1	13.2	28.1	19.3	41.0	11.4	0.026	.87	0.09

Woodcock–Johnson III standard score $M = 100$, $SD = 15$. Clay measures are raw scores.
[a]Subtests yielded significant differences between groups on pretest.
*$p < .05$.

Rose and Meyer's (2002) three principles of UDL. LBD provides students with multiple means of representation, multiple means of action and expression, and multiple means of engagement. Across the LBD e-books, WiggleWorks e-books, and the phonemic awareness and phonics software, students read, responded, and interacted with stories and activities that provided multiple pathways for learning. The LBD e-books represents a rigorous application of UDL with the embedded strategy instruction, multimedia, pedagogical coaches, and varied student response options. The WiggleWorks e-books and the phonemic awareness and phonics software also provided multimodal learning and options for expression. In combination, the application of the UDL principles seen in the LBD instructional approach shows promise for improving the reading comprehension of young students with significant intellectual challenges. The results add to research on UDL-based approaches to literacy with other struggling readers (Dalton et al., 2002; Hall & Murray, 2009; Proctor et al., 2007; Proctor et al., 2009).

The LBD group's improved performance on the WJ-III Passage Comprehension subtest is noteworthy in that emphasis on comprehension is a cornerstone of the LBD approach. There are several possible explanations for this result. Baseline observations revealed that prior to this study three of the five LBD classrooms and two of the four control classrooms relied on skills-based curricula and methods focusing on single word recognition, basic functional vocabulary often at the isolated single word level, and phonics. In addition, reading materials largely consisted of phonetically controlled readers with black line illustrations and worksheets for comprehension and vocabulary skills practice. Classroom observations indicate that the initially skills-based LBD classrooms moved to a more comprehensive approach with increased attention to comprehension, whereas the skills-based control classrooms did not. Although skills-based instructional programs remain the norm for students with significant intellectual disabilities (Erickson & Koppenhaver, 1995; Gurry & Larkin, 1999; Katims, 2000), the results of this study add to the research demonstrating the promise of comprehensive approaches that develop literacy skills in meaningful contexts (Erickson et al., 2009; Skotko et al., 2004). Consistent with the findings of Houston and Torgesen (2004), the LBD focus on comprehension instruction in the context of reading real stories may have proved beneficial for these students with significant intellectual disabilities.

Gains on the WJ-III Word Attack subtest were strong in effect. One explanation might be that students in the LBD group had more opportunities to listen to the audio narration of the stories in the LBD and WiggleWorks e-books and to practice reading aloud with the audio-record feature. As with the reading comprehension strategies, students had on-demand support in the form of pedagogical agents who modeled the read-aloud process and decoding animations that highlighted pronunciation of the onset-rhymes of phonetically regular words. It may be that these students had more practice than their peers in the control group developing sound symbol relationships of words frequently encountered in beginning level texts.

Differences in the two groups' performance on the WJ-III Listening Comprehension composite score based on the Understanding Directions and Oral Comprehension subtests indicated a strong effect and should be viewed conservatively. This finding may be partially because of two functions of the intervention software that are absent from printed text. First, students interacted with language in multiple modes as they viewed, listened to, read, and interacted with the software such as accessing embedded glossary items, using text to speech to hear the story read aloud, and accessed embedded video to support background knowledge. Second, unlike printed text, the LBD e-books provided multiple opportunities for students to practice responding to embedded reading comprehension strategy prompts. Accompanying pedagogical agents elicited conversations between students and teachers and provided models for how to talk about stories. Skotko et al.'s (2004) research has shown that this kind of rich language exchange about books is especially helpful to children with significant intellectual disabilities.

The effect size for *Concepts About Print* was also strong. This finding may be explained by functions of the software that explicitly align with skills measured by this assessment. For example, synchronized text to speech with word-by-word highlighting repeatedly demonstrates the left-to-right, top-to-bottom motion of reading text and clearly distinguishes text from images. Students had repeated opportunities to practice these skills on the computer, which may have made it easier for them to apply them to print versions of text.

The ability to embed agents that provide instructional scaffolds and supports distinguishes e-books from print texts and may provide key learning supports beneficial to young students with significant intellectual disabilities. Further research is warranted to determine precisely which instructional scaffolds and supports are most beneficial for students within this group who vary widely in abilities and needs.

Limitations and Implications

There are several limitations of the study. The small sample size of 16 students resulted in an underpowered design. Clearly, a study with a larger sample is needed, preferably one that would allow analysis of learning outcomes in relation to specific student characteristics and which would nest student effects within classroom effects. Another limitation was our reliance on the schools' determination that each student demonstrated significantly subaverage intellectual functioning and deficits in two or more adaptive skills areas (Luckasson et al., 1992). Pretest reading achievement data indicated significant differences between the LBD and control students on two reading subtests. Although we addressed this to some degree by employing ANCOVA to analyze the posttest performance adjusted for pretest scores, it is possible that unknown group differences influenced the outcomes. Future research should use pretest information to stratify students based on reading, language, and cognitive abilities and randomly assign students to treatment. A third limitation was teachers' sporadic reporting of software use, affecting documentation of fidelity of treatment data. The use of software tracking would have provided valuable information about students' use of the software. Given the kind of customized learning that is needed for all students to progress, it is important to track their use of various features and to correlate usage with learning outcomes and student characteristics. This type of information is needed to refine UDL e-book design principles and instruction for this population. Fourth, we relied on pre-post standardized reading achievement assessments that required verbal responses. Future research should include nonverbal literacy assessment, similar to those developed by Browder et al. (2008). And although not a limitation per se, our experience with this work highlights the need to conduct longitudinal research that follows students over time to determine the effect of ongoing scaffolded literacy learning and its implications for students' academic and life success.

Conclusion

These results provide some additional support for the view that children of primary school age with significant intellectual disabilities can benefit from evidence-based reading instruction (NRP, 2000) applied in meaningful literacy contexts where learning is scaffolded in relation to students' needs (Erickson et al., 2009; Erickson & Koppenhaver, 1995; Katims, 2000). The study also suggests e-book design principles and provides preliminary groundwork for applying UDL principles to a literacy instructional approach that emphasizes reading for understanding, developing reading skills in context, incorporating universally designed e-books, and deploying instructional software strategically to address all aspects of reading development. Literacy instruction that focuses exclusively on sight word recognition and functional literacy may limit the potential of children with significant intellectual disabilities. We hope that the promise found in the results of this study, although limited, will lead to further investigation of the potential of universal design and technology in expanding opportunities for access, participation, and progress in the general education curriculum for young students with significant intellectual disabilities.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interests with respect to the authorship and/or publication of this article.

Financial Disclosure/Funding

This work was supported by a grant from the U.S. Department of Education, Office of Special Education Programs to CAST, Inc. (grant number H0324D020059). An earlier version of the LBD prototype was developed with support from the Joseph P. Kennedy, Jr. Foundation.

References

Almasi, J. F. (2003). *Teaching strategic reading processes*. New York, NY: Guilford.

Al Otaiba, S., & Hosp, M. (2004). Service learning: Training preservice teachers to provide effective literacy instruction to students with Down syndrome. *Teaching Exceptional Children*, *36*(4), 28–35.

Berk, L. E., & Winsler, A. (1995). *Scaffolding children's learning: Vygotsky and early childhood education.* Washington, DC: National Association for the Education of Young Children.

Browder, D. M., Ahlgrim-Delzell, L., Courtade, G., Gibbs, S. L., & Flowers, C. (2008). Evaluation of the effectiveness of an early literacy program for students with significant developmental disabilities using group randomized trial research. *Exceptional Children*, *75*, 33–52.

Browder, D. M., Gibbs, S., Ahlgrim-Delzell, L., Courtade, G., & Lee, A. (2007). *Early Literacy Skills Builder*. Verona, WI: Attainment Company.

Browder, D. M., Wakeman, S. Y., Spooner, F., Ahlgrim-Delzell, L., & Algozzine, B. (2006). Research on reading instruction for individuals with significant cognitive disabilities. *Exceptional Children*, *72*, 392–408.

Clay, M. M. (2000a). *Letter Identification*. Portsmouth, NH: Heinemann.

Clay, M. M. (2000b). *Concepts About Print*. Portsmouth, NH: Heinemann.

Cognition and Technology Group at Vanderbilt. (1993). Designing learning environments that support thinking: The Jasper series as a case study. In T. M. Duffy, J. Lowyeh, & D. H. Jonassen (Eds.), *Designing environments for constructive learning* (pp. 9–36). Berlin, Germany: Springer-Verlag.

Collins, A., Brown, J. S., & Newman, S. E. (1989). Cognitive apprenticeship: Teaching the crafts of reading, writing, and mathematics. In L. B. Resnick (Ed.), *Knowing, learning, and instruction: Essays in honor of Robert Glaser* (pp. 453–494). Hillsdale, NJ: Lawrence Erlbaum.

Dalton, B., & Coyne, P. (2002). *Developing the thinking reader technology-based instructional approach to support beginning reading in children with mental retardation* (Final report to the Joseph P. Kennedy Foundation). Peabody, MA: CAST.

Dalton, B., Pisha, B., Coyne, P., Eagleton, M., & Deysher, S. (2002). *Engaging the text: Reciprocal teaching and questioning strategies in a scaffolded learning environment* (Final report to the U.S. Office of Special Education). Peabody, MA: CAST.

Dalton, B., & Proctor, C. P. (2007). Reading as thinking: Integrating strategy instruction in a universally designed digital literacy environment. In D. S. McNamara (Ed.), *Reading comprehension strategies: Theories, interventions, and technologies* (pp. 423–442). Mahwah, NJ: Lawrence Erlbaum.

Dalton, B., Zeph, L. Coyne, P., & Enright, B. (2006). *Literacy by Design: Creating universally designed reading environments for students with significant cognitive disabilities* (U.S. Department of Education, Office of Special Education Programs, Final Report H0324D020059). Wakefield, MA: CAST.

Erickson, K. (2004). *MEville to WEville*. Roseville, MN: Ablenet.

Erickson, K., Hanser, G., Hatch, P., & Sanders, E. (2009). Research-based practices for creating access to the general curriculum in reading and literacy for students with significant intellectual disabilities (Final report to the Council of Chief State School Officers, Assessing Special Education Students, State Collaborative on Assessment and Student Standards). Chapel Hill, NC: Center for Literacy and Disabilities Studies. Retrieved from http://www.ncksec.net/docs/notices/certified/ELA_AAS__CLDS_-Final.pdf

Erickson, K. A., & Koppenhaver, D. A. (1995). Developing a literacy program for children with severe disabilities. *Reading Teacher*, *48*, 676–683.

Gurry, S. & Larkin, A. (1999). Literacy learning abilities of children with developmental disabilities. *Currents in Literacy, 2*. Retrieved from http://www.lesley.edu/academic_centers/hood/currents/v2n1/gurry_larkin.html

Hall, T., & Murray, E. (2009). *Monitoring student's progress towards standards in reading: A universally designed CBM system* (Final Report H327BO50009). Washington, DC: U.S. Department of Education: Office of Special Education Programs.

Hedrick, B. W., Katims, S. D., & Carr, J. N. (1999). Implementing a multimethod, multilevel literacy program for students with mental retardation. *Focus on Autism and Other Developmental Delays*, *14*, 231–239.

Houston, D., & Torgesen, J. (2004). *Teaching students with moderate disability to read: Insights from research*. Tallahassee: Florida Department of Education, Bureau of Instructional Support and Community Services.

Huck, S. W. (2000). *Reading statistics and research* (3rd ed.). New York, NY: Longman.

Individuals With Disabilities Education Act Amendments of 1997, H.R. 5, 105th Cong. (1997). Retrieved from http://www.ed.gov/offices/OSERS/Policy/IDEA/index.html

Individuals With Disabilities Education Improvement Act of 2004, H.R. 1350, 108th Cong. (2004). Retrieved from http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=108_cong_public_laws&docid=f:publ446.108

Island Adventure [Computer software]. (1997). San Francisco, CA: Riverdeep.

Jackson, R. (2005). *Curriculum access for students with low-incidence disabilities: The promise of universal design for learning.* Wakefield, MA: National Center on Accessing the General Curriculum. Retrieved from http://www.cast.org/publications/ncac/ncac_lowinc.html

Katims, S. D. (2000). Literacy instruction for people with mental retardation: Historical highlights and contemporary analysis. *Education and Training in Mental Retardation and Developmental Disabilities*, *35*, 3–15.

Kliewer, C., & Biklen, D. (2001). School's not really a place for reading: A research synthesis of the literate lives of students with severe disabilities. *Journal of the Association for Persons with Severe Handicaps*, *26*, 1–12.

Koppenhaver, D. A., Coleman, P. P., Kalman, S. L., & Yoder, D. E. (1991). The implications of emergent literacy research for children with developmental disabilities. *American Journal of Speech-Language Pathology*, *1*(1), 38–44.

Luckasson, R., Schalock, R. L., Spitalnik, D. M., Spreat, S., Tassé, M., Snell, M. E., . . . Craig, E. M. (1992). *Mental retardation: Definition, classification and systems of supports*. Washington, DC: American Association on Mental Retardation.

MacArthur, C. A., Ferretti, R. P., Okolo, C. M., & Cavalier, A. R. (2001). Technology applications for students with literacy problems: A critical review. *Elementary School Journal*, *101*, 273–301.

McLaughlin, M. J. (1999). Access to the general education curriculum: Paperwork and procedure or redefining special education. *Journal of Special Education Leadership*, *12*(1), 9–14.

Mefferd, E. P., & Pettegrew, S. B. (1997). Fostering literacy acquisition of students with developmental disabilities: Assisted reading with predictable trade books. *Reading Research and Instruction*, *36*, 177–190.

Meyer, A., & Rose, D. H. (1998). *Learning to read in the computer age.* Cambridge, MA: Brookline Books.

Meyer, A., & Rose, D. H. (2005). The future is in the margins: The role of technology and disability in educational reform. In D. H. Rose, A. Meyer, & C. Hitchcock (Eds.), *The universally designed classroom: Accessible curriculum and digital technologies* (pp. 13–35)*.* Cambridge, MA: Harvard Education Press.

National Reading Panel. (2000). *Teaching children to read: An evidence-based assessment of the scientific research literature on reading and its implications for reading instruction: Reports of the subgroups.* Washington, DC: National Institute of Child Health and Development.

No Child Left Behind Act of 2001, Pub. L. No. 107-110 (2002). Retrieved from http://www2.ed.gov/policy/elsec/leg/esea02/index.html

Ocean Adventure [Computer software]. (1997). San Francisco, CA: Riverdeep.

O'Neill, L. M., & Dalton, B. (2002). Supporting beginning reading in children with cognitive disability through technology. *Exceptional Parent*, *32*(6), 40–43.

Pisha, B., & Coyne, P. (2001). Smart from the start: The promise of universal design for learning. *Remedial and Special Education*, *22*, 197–203.

President's Commission on Excellence in Special Education Report. (2002). *A new era: Revitalizing special education for children and their families*. Retrieved from http://www2.ed.gov/inits/commissionsboards/whspecialeducation/reports/index.html

Proctor, C. P., Dalton, B., & Grisham, D. L. (2007). Scaffolding English language learners and struggling readers in a universal literacy environment with embedded strategy instruction and vocabulary support. *Journal of Literacy Research*, *39*, 71–94.

Proctor, C. P., Uccelli, P., Dalton, B., & Snow, C. E. (2009). Understanding depth of vocabulary online with bilingual and monolingual children. *Reading and Writing Quarterly*, *25*, 311–333.

Rose, D., & Meyer, A. (2002). *Teaching every student in the digital age: Universal design for learning.* Alexandria, VA: ASCD.

Skotko, B. G., Koppenhaver, D. A., & Erickson, K. A. (2004). Parent reading behaviors and communication outcomes in girls with Rett syndrome. *Exceptional Children*, *70*, 145–166.

Strangman, N., & Dalton, B. (2005). Technology for struggling readers: A review of the research. In D. Edyburn, K. Higgins, & R. Boone (Eds.), *The handbook of special education technology research and practice* (pp. 545–569). Whitefish Bay, WI: Knowledge by Design.

Wehmeyer, M. L., Smith, S. J., Palmer, S. B., Davies, D. K., & Stock, S. E. (2004). Technology use and people with mental retardation. In L. M. Glidden (Ed.), *International review of research in mental retardation* (Vol. 29, pp. 293–337). San Diego, CA: Academic Press.

WiggleWorks [Computer software]. (1996). New York, NY: Scholastic.

Wood, D., Bruner, J. S., & Ross, G. (1976). The role of tutoring in problem solving. *Journal of Child Psychology and Psychiatry*, *17*, 89–100.

Woodcock, R. W., McGrew, K., & Mather, N. (2001). *Woodcock–Johnson III Tests of Achievement*. Itasca, IL: Riverside.

About the Authors

Peggy Coyne, EdD, is a research scientist at CAST. Her interests include universal design for learning and literacy and the intersection of these two in relation to preschool and elementary children and their teachers and parents.

Bart Pisha, EdD, worked at CAST for 20 years, leaving his position as director of research in 2005. Currently, he is principal of a consulting and tutoring firm whose mission is to enhance college-bound students' chances of success.

Bridget Dalton, EdD, is an assistant professor at Vanderbilt University's Peabody College of Education. Her interests include digital literacies, new media, and struggling readers.

Lucille A. Zeph, EdD, is director of the Center for Community Inclusion and Disability Studies and associate professor of education at the University of Maine. Her current interests include inclusive education for students with intensive support needs and universal design and access.

Nancy Cook Smith, PhD, is project psychometrician at the Science Education Department of the Harvard-Smithsonian Center for Astrophysics. Her interests include classroom assessment, measurement models in education and psychology, and assessments of teachers' and students' scientific misconceptions.