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Addressing Learning Disabilities With UDL and Technology: Strategic Reader

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Abstract

CAST created *Strategic Reader*, a technology-based system blending Universal Design for Learning (UDL) and Curriculum-Based Measurement (CBM) in a digital learning environment to improve reading comprehension instruction. This experimental study evaluates the effectiveness of Strategic Reader using two treatment conditions for measuring progress (online vs. offline). Using both quantitative and qualitative data analysis, strong evidence is found that students using the online tool experience significant growth in comprehension scores. The difference in score growth in the online versus offline conditions is especially large for students with learning disabilities (LDs): Only in the online progress monitoring condition do LD students experience a statistically significant score increase. In addition, students with LDs report being substantially more engaged by (and with) *Strategic Reader*, finding many aspects of the tool differentially more helpful than their general education peers. In sum, the results provide promising paths for both curricular design and further research in the design of digital environments.

Keywords

Universal Design for Learning, reading comprehension, technology, learning disabilities

Students with learning disabilities (LDs) most often encounter obstacles when reading to learn, such as difficulties decoding or trying to comprehend content without sufficient background knowledge (Lyon, 2003). Such challenges raise considerable barriers to academic performance. Teachers are left trying to adapt curricula to meet the varied needs of their students while devising creative ways to engage *all* students (Coyne et al., 2006). Teachers are in need of innovative supports, strategies, and tools that will make it possible to meet the educational needs of all students. In researching and developing universally designed learning environments since the 1980s, CAST has sought to fundamentally alter the relationship between children and literacy by using technology to embed reading strategy instruction directly into high quality educational content for all students. This work draws on a significant research base supporting reading strategy instruction to develop comprehension in students with and without disabilities (National Reading Panel [NRP], 2000; Swanson, 1999).

Literature Review

Universal Design for Learning

Universal Design for Learning (UDL) is a framework for instructional design, based on neuroscience and interpreted from an educational perspective, which is flexible and supportive for all learners, including those with LDs, so that instructional goals, assessments, methods, and materials are usable and accessible by all (Hall, Meyer, & Rose, 2012; Meyer, Rose, & Gordon, 2014). Meyer and Rose (1998) developed the UDL framework composed of three principles. The first principle—to provide multiple means of representation—calls for anticipating and addressing in advance any physical, perceptual, and cognitive barriers that might interfere with students' learning. For example, the presentation of material both visually and orally was found supportive of learning (Madaus, Scott, & McGuire, 2003), as have books on tape where access to text is auditory (Burgstahler, Duclos, & Turcotte, 2000; Elacqua, Rapaport, & Kruse, 1996; Finn, 1998). In Dalton and team's 2011 research on digital reading environments using the UDL framework, results suggest that monolingual and bilingual fifth-grade students benefited from reading age-appropriate e-text universally designed to provide access to all users (Dalton, Proctor, Uccelli, Mo, & Snow, 2011). The second UDL principle—to provide multiple means for

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action and expression—recognizes that variability with which learners plan, strategize, and perform learning tasks, and in the ways they express what they know (Rose & Meyer, 2006). In Coyne, Pisha, Dalton, Zeph, and Smith's (2012) study, using a digital reading environment with students with more severe cognitive disabilities, the team found that the participants in program with multimodal options for learning and expression outperformed students taught using traditional offline reading strategies at the $p = .02$ level (effect size 1.44). The third principle of UDL—to provide multiple means of engagement—emphasizes that learners are variable in the ways in which they engage or are motivated to learn; there are different motivators for students to learn, and what may work for one student may cause disengagement for another (Rose & Meyer, 2006). Empirical support for this principle suggests that recruiting interest, sustaining effort and persistence, and self-regulation can result in improved learning outcomes for students (Roseth, Johnson, & Johnson, 2008).

Curriculum-Based Measurement (CBM)

CBM, a form of formative assessment, is best explained as "any set of measurement procedures that use direct observation and recording of a student's performance in a local curriculum as a basis for gathering information to make instructional decisions" (Shinn, 1989, p. 62). CBMs were developed to function as "academic yardsticks" to monitor students' growth in basic academic skills. Substantial research over the past three decades has established CBM as a method highly suited to monitor student progress to improve student achievement (Stecker, Fuchs, & Fuchs, 2005). A 20-year line of empirically validated research demonstrated that CBM is beneficial for student learning when teachers monitor student data and then make instructional decisions (L. S. Fuchs & Fuchs, 1986, 2001; Jones & Krouse, 1988; Stecker & Fuchs, 2000). When teachers use CBM to monitor student growth, evaluate performance, and change instruction, students make greater achievement gains than students of teachers not using formative evaluation procedures (Espin & Foegen, 1996). Use of CBM has been shown to improve teacher decision making for students with disabilities (SWD) in general education settings (D. Fuchs, Fuchs, & Fernstrom, 1993).

Reciprocal Teaching Strategies

NRP analyzed 203 studies on text comprehension instruction and concluded, "Comprehension instruction can effectively motivate and teach readers to learn and to use comprehension strategies that benefit the reader" (NRP, 2000, pp. 4–6). They further concluded that multiple strategy instruction carried out in natural classroom settings was more beneficial than the teaching of individual strategies. A wealth of research evidence strongly supports the teaching of Palincsar and Brown's (1984) reading comprehension strategies (summarizing, predicting, questioning, and clarifying) to students with and without disabilities (NRP, 2000; Rosenshine & Meister, 1994; Swanson, 1999; Wong, 1991). These strategies specifically teach learners to engage in dialogue about the text across disciplines by breaking down the types of comprehension we do as readers into the abovementioned categories and by providing strategies to address each in relation to text. The first universally designed reading comprehension improvement program, Thinking Reader, researched and developed by CAST, embedded reciprocal teaching strategies in its novels. Drummond et al. (2011) show that Thinking Reader not only significantly improved student reading scores statistically at the .03 level, but that qualitatively teachers also altered instruction to focus more on reading strategies based on classroom observational data (Dalton, Pisha, Eagleton, Coyne, & Deysher, 2002).

Sociocultural Theory

The sociocultural theory of literacy emphasizes that literacy involving readers, writers, and their interactions that are situated within a community, discipline, or culture are shaped by particular assumptions, issues, and history (Nystrand, 2006; Olson, 2007; Prior, 2006). In their meta-analysis, Graham and Hebert (2010) identified strong literacy skills as a key to student success in school, college, and career, providing three strong recommendations for improvement. First, a large part of the literacy experience is the functional activities in reading and writing (Fitzgerald & Shanahan, 2000). Second, the connection of reading and writing is nearly inherent given the strong common base from knowledge and cognitive processes (Shanahan, 2006). And third, these are communication activities; writers should gain insight into reading by creating their own texts (Shanahan, 2006) leading to better comprehension of text. In addition, working together with peers supports students' literacy (the average weighted effect size for peers working together was .72 in Graham & Perin's, 2007 meta-analysis). Making students' writing public on the Internet also gives them more opportunity to receive frequent, constructive feedback (Lenhart, Arafeh, Smith, & Macgill, 2008).

These four pillars of literature support the focus of this research: UDL, CBM, reciprocal teaching, and sociocultural theory. These areas come together to inform, provide appropriate and engaging practice, and build a foundation on which this research study has been created. The manipulated variable in this study is the delivery mechanism of CBM.

The web-based *Strategic Reader* tool was developed to determine whether the addition of curriculum-based formative assessment to a universally designed interactive digital reading environment would lead to better outcomes for all students, especially those with disabilities and modifications

in reading instruction. Strategic Reader integrated formative assessment into a highly supported literacy environment. Its reading environment allows access for all readers to digitized texts and provides scaffolds to support comprehension. This work is predicated on the prior success of a reading environment created and researched at CAST (Dalton et al., 2002).

Research Questions

Researchers designed this study to explore the synergy between two proven effective approaches: UDL and CBM. The three research questions this study was designed to answer are as follows:

Research Question 1: Is the implementation of CBM-UDL more efficient and effective for teachers and students than a more traditional offline implementation of CBM when using a UDL reading environment?
Research Question 2: Is the technology-based approach to monitor student performance in reading more effective in improving student performance on standards-based measures of reading comprehension?
Research Question 3: Does implementing technology-based CBM in a UDL reading environment facilitate teachers' use of CBM to inform instruction central to state standards?

The Strategic Reader Tool

There are three main components in the design of Strategic Reader: (a) a supported and interactive digital reading environment based on UDL principles and previous research, (b) a forum for ongoing teacher-to-student and student-to-student topical discussion, and (c) embedded CBM to monitor student progress. Within the Strategic Reader tool, each component was accessible to teachers and students, with varied options and flexibility designed to meet student needs. In addition, the teacher side of the tool contains several features and resources to support teachers' specific tool use, such as access to aggregate and individual students' responses and scores, resources to support interpretation of student data, and making instructional interventions. Although Strategic Reader tool was developed as a prototype for this research project and we intend with this and future research to both revise and make the tool more available, at this time, there is no access to Strategic Reader. The following sections describe the tool as implemented in this research project.

Digital Reading Environment

The digital reading environment is a computer-supported reading environment that integrates instruction in reading strategies into high quality, age-appropriate, middle school novels to address English Language Arts (ELA) standards on applying reading strategies to understand and interpret texts. In the digital reading environment, students had access to support features, including text-to-speech, a dictionary and multimedia glossary, the flexibility to change font size and contrast, text highlighting, and bookmarking. In addition, students respond to embedded strategy prompts as they read, and responses are recorded online in individual work logs that students and teachers can review at any time. In the reading environment, teachers could modify how much or little support a student received (with options including text highlighting and sentence starters).

Books. In Strategic Reader, students access digital versions of four age-appropriate, award-winning middle school novels. Considering middle school instruction in the ELA intentionally seeks popular, highly engaging texts, which are aligned with State standards, the Strategic Reader's materials were also aligned with national and state ELA standards as this study was conducted prior to the development of the Common Core State Standards. The digital novels contained the exact same text as the print versions, but contained many customizable features that made the novels more accessible and supported for struggling readers, including those with disabilities. Students could enlarge font, change color contrasts, or use voice assisted reading (text to speech).

Embedded reciprocal teaching questions. As students read literature in this online environment, they responded to embedded reciprocal teaching strategy questions. Students read a passage from chosen text, have the option to highlight important parts of the text, respond to the type of reciprocal strategy (question, summarize, clarify, predict, visualize), and then compose their response in text or auditory recording. When answering the reciprocal teaching questions, students had two additional and optional supports available. Two animated pedagogical agents are available for on demand support. *Pen* was designed to support understanding by providing a model or example of a response to the reciprocal teaching strategy question. Students may hear, as well as read, the model responses specific to the particular strategy. *Eko* provided students with a peer-like explanation of the directions specific to the screen. Both agents, rendered as colorful characters, were available to students for use throughout the tool. On the teacher's side of Strategic Reader, users are able to view student responses to reciprocal teaching strategy comprehension questions specific to each novel, chapter, and page in the tool. Teachers may view and analyze student responses collectively as a class, or in each individual's log. All responses are accessible for teachers and available for student coaching sessions or class discussions in relation to instructional goals.

Progress Monitoring Using CBM

CBMs were built into the architecture of the Strategic Reader tool to support periodic and systematic progress monitoring. Embedding these measures into the Strategic Reader reduces the burden on teachers in the development, administration, scoring, and graphing of traditional CBM process. We created CBM in the Strategic Reader to help teachers focus on data, analysis, and the need for intervention in reading. The teacher assigns progress monitoring to the class or an individual in the tool. Once assigned, the student is automatically delivered the progress monitoring to complete before accessing other areas of the Strategic Reader (e.g., books, questions, forum).

The tool notifies students that the session will begin with progress monitoring and they have a choice of which measure and topic to address. There are three distinct measures embedded in Strategic Reader: (a) oral reading fluency, which measures a student's fluency, accuracy, and prosody of a text; (b) maze, an exercise in reading comprehension where words are removed from a passage and the student fills in blank spaces with one of three options available in a dropdown menu; and (c) reading comprehension strategies measures (summarizing, predicting, questioning, and clarifying). The program administers each measure, and automatically calculates several scores. However, the oral reading fluency is partially scored by the classroom teacher using the Strategic Reader. Teachers listen to the student recording collected and code the errors using Strategic Reader (e.g., misidentification, substitution, omission). The tool automatically calculates and displays results. Results are instantly delivered to the teacher for interpretation and analysis. Students receive CBM probe results immediately.

From the teachers' side, teachers assign progress monitoring tasks, score when needed, and view student results at the class and individual levels. They may adjust the amount of support students experience while using the Strategic Reader (such as highlighting critical information, providing sentence starters, etc.). The tool automatically maintains and displays both aggregate (i.e., entire class results) and time series data (i.e., over time for individuals) for all measures administered. All scores are displayed in graphic and tabular forms enabling students and teachers to *see* a picture of performance over time and to determine whether progress is adequate to meet specific standards allowing multiple methods for comparison. Given the web-based delivery of Strategic Reader, students, teachers, and parents have access to the tool from any computer with an internet connection. While we had no formal parent involvement in the project, the tool was described in a letter to parents that included the program URL and an explanation of how to login with their child.

Online Forum

The online forum, based on the sociocultural theory of learning, is a setting for student-to-student and student-to-teacher discussions. The forum is accessed in Strategic Reader and can be used for discussing the texts, receiving feedback, and connecting with teachers and peers. In the reciprocal teaching strategies design, teachers engage students in oral dialogue about the text to develop reading comprehension skills. While using the Strategic Reader with embedded reciprocal teaching prompts, teachers can conduct classwide oral discussions of the novels read as well as post questions and discussion items in the forum for comment and written dialogue about the novels reinforcing the reading and writing connection. Students use the forum to continue class discussions as well as address new ideas and questions posted by teachers or students. Frequently, teachers opened or concluded classes with time to interact on the forum.

While the forum can be coordinated and monitored by the teacher, the teacher can also engage as a participant. From the teacher's side of the Strategic Reader, teachers may read and comment on students' dialogues, start new discussions, or close completed topics. In addition, teachers could remove any dialogue deemed inappropriate.

Method

A mixed-method study design, of quantitative and qualitative methodology, was used to analyze whether UDL-CBM embedded directly into an instructional digital environment supported better reading outcomes for all students, particularly those with disabilities, and determine whether providing support for teacher instructional decision making and differentiated instruction for individual students leads to appropriately supported reading. The study design included two treatment conditions. In both conditions, students and teachers had the same novels online, with identical supports, scaffolds, work logs, and the forum for dialogue. The difference between treatment conditions was how teachers and students were presented with and accessed progress monitoring measures. Treatment 1 condition (Strategic Reader with online CBM) had all progress monitoring measures, administration, scoring, and graphing online, while Treatment 2 (Strategic Reader with offline CBM) included progress monitoring in a traditional offline paper-and-pencil structure requiring teacher administration, scoring, and graphing.

Subjects and Setting

Selection process. We recruited four middle schools from four districts outside a large metropolitan area in the Northeast. All schools applied an inclusion model of providing services for students with disabilities. Implementation of

that model varied to some degree across schools. For example, two schools used a model of general and special education teacher teams in inclusive co-taught classes. The other two schools provided supports for students with disabilities with a special education teacher or paraprofessional in the general classroom. In this model, support was focused on students with disabilities; however, both adults in the classroom provided instruction and support for all students. All four schools also provided some pullout services for students with disabilities for additional intervention/instruction. The schools represented diverse backgrounds in terms of socioeconomic, racial, and disability status. Another criterion for school recruitment included the technology infrastructure of the building, hardware access, Internet capability, and bandwidth.

We then recruited ELA teachers and special education teachers teaching in the ELA area to participate in the study with their sixth-, seventh-, and eighth-grade classes. Ten teachers volunteered to participate representing 14 classrooms in the four schools. These classes included students with identified disabilities as well as students struggling in literacy.

Participating students and teachers. We began the study with 14 classrooms with a total of 307 students. Parental permission and student assent were secured for 284 students. Class sizes varied greatly in each school (ranging from 17 to 36 students per class). In explanation for this variation, some classes were specialized supplemental ELA offerings for all students; others were general classroom populations of up to 36 students in integrated classes. Interestingly, these larger classes were also classes that contained mixed grade levels of students from sixth to eighth grades. The mean age for students completing the study was 11 years 6 months. English was the primary language for 88% of the students, and 12% spoke English and either Spanish or Portuguese. The socioeconomic status and racial composition of the participant group were fairly representative of the four districts. Boys made up 50.7% of the group at 144, and there were 140 girls (49.2%); 66% of the students were White, 20% African American, 12% Hispanic, and 2% Asian. Forty-eight percent of all participating students received free or reduced priced lunch.

In total, 73 of our participants were identified as students with disabilities with an Individualized Education Plan. Of these students, 64 were identified as students with LDs based on the district and state guidelines, and 8 students were identified as other health impaired (hearing and attention deficit hyperactivity disorder [ADHD], 1 was identified with a hearing impairment). Six of the students with LDs were also identified as having attention deficits, and 3 were identified for speech and language. In addition, 8 students were on 504 plans, receiving services for attention challenges (6) and mobility supports (2).

Table 1. Student Characteristics by Instructional Condition.

Condition	Treatment 1 (SR with online CBM)	Treatment 2 (SR with offline CBM)
Age (months)		
M (*SD*)	148.2 (5.89)	136.7 (6.11)
Gates reading score		
M (*SD*)	47.71 (17.04)	68.10 (18.254)
Gender		
Male	78	66
Female	76	64
Race		
White	90	97
Black	35	21
Hispanic	27	8
Asian	2	4
Students with disabilities		
Learning disabilities	36	28
ADHD	5	6
Other health impaired	3	5
Students with 504 plan	2	6

Note. SR = Strategic Reader; CBM = Curriculum-Based Measurement; ADHD = attention deficit hyperactivity disorder.

There were some statistical differences between groups based on reading ability before engaging with the Strategic Reader. Considering all participating students' reading pretest scores, students in the Treatment 1 group (online CBM) had a mean score of 47.8 (*SD* 17.04) while students in the Treatment 2 group (offline CBM) had a mean reading pretest score of 68.3 (*SD* 18.25). Moreover, there were differences between the treatment groups for participating students with disabilities. Students with disabilities' mean reading pre-test score in Treatment 1 was 38.18 (*SD* 16.33) and Treatment 2 group's mean reading pre-test score was 55.61 (*SD* 20.99). This difference was uncontrollable due to assignment to condition at the teacher level. Information on characteristics of students by condition is presented in Table 1.

Ten teachers participated in the study; eight were female, and two were male. Seven of the 10 teachers were general education ELA-certified teachers, the remaining 3 teachers were special education teachers. The special education teachers team-taught in the general education ELA classes. All teachers were certified at the secondary level and averaged 16.8 (*SD* 9.7) years of teaching experience. As noted above, all teachers expressed an interest in participating in the study to use Strategic Reader in their classroom(s). Teachers were randomly assigned to condition after accepting to volunteer for the project. All teachers participated throughout the duration of the study. Research was conducted in 14 classrooms with the 10 participating teachers.

Two teachers elected to conduct the study in two classes for a total of 5 teachers and 7 classrooms per condition.

Implementation

Two treatment conditions were created to analyze whether the embedding of progress monitoring measurements into a digital reading environment is more effective than traditional CBM (paper-and-pencil tasks) in improving students' reading comprehension and progress toward reading standards in a digital UDL environment. Assignment to treatment condition was completed at the building level due to concern for contamination at the teacher level. Teachers were randomly assigned to condition for the CBM experience. Conditions were based on our treatment versus control structure of an entirely digital experience (Treatment 1, online CBM) versus digital reading with traditional CBM (Treatment 2, offline CBM). The *only* difference between the treatment conditions was how the CBMs were administered.

Procedures

Research was conducted in ELA classrooms during the regular academic school year for an 11- to 12-week period. During this time, students in both conditions read a minimum of two of the four available novels with identical supports and scaffolds (the digital novels contained the exact same text as the print versions). Although not all students read the same novels across classrooms, the level, genre, difficulty level, and topic areas were very similar. In addition, students responded to embedded reciprocal teaching strategy prompts as they read, and their responses were recorded online in individual work logs. Class sessions were between 40 and 55 min in length in both treatment conditions. Teachers generally used Strategic Reader 3 to 4 days each week, some (8 teachers) occasionally assigning reading and responding in the tool as homework. Teachers did provide instruction in ELA as well. Time using Strategic Reader during classes varied from as little as 20 min to as much as the entire class depending on the teachers' instructional goals for the day. Students in both conditions also participated in teacher and student directed use of the forums for student-to-student and/or student-to-teacher dialogue regarding the novels. This too occurred as an expectation of class time as well as homework. Last, the CBM measures of oral reading fluency and maze were administered twice per month, and the reciprocal teaching strategies measure was administered at the start and completion of each novel. Students in online CBM, Treatment 1, condition completed these measures online, while those in offline CBM, Treatment 2, were administered measures in traditional paper mode.

Training

CAST researchers provided the training for all participating teachers and students on use of Strategic Reader. To maintain consistency and quality of implementation, researchers visited all classrooms on a regular basis (every other week). In the classrooms, the researchers observed, coached teachers and students in the use of the tool, demonstrated additional features and functions, assisted in the analysis and interpretation of progress monitoring scores, and discussed data in relation to reading strategies.

Teacher training. Initial training for teachers in both treatment conditions took place at CAST in the form of a 2-day professional development experience for teachers with three focus areas: (a) software use and management of the digital reading environment (layout and functions of the tool), (b) three CBMs (reciprocal teaching strategies, oral reading fluency, and maze), and (c) scoring of the CBM, interpretation of student performance, and decision making using CBM.

In addition, all participating teachers were guided in how to use the resources through the teacher's side of the Strategic Reader. Teachers were trained on how to access this content and were given an overview of all support materials. These included related research-based articles, examples of UDL, CBM information, reciprocal teaching strategies with example responses and teaching strategies, forums with recommended topics related to the novels in the tool, and teaching resources and interventions for use inside and outside of the digital reading environment. Teachers participated in follow-up instructional sessions that included onsite observations, coaching sessions, and a meeting at the completion of each novel. These sessions focused on process, progress, and implementation needs.

The key difference in the training experience between teachers in Treatment 1 and Treatment 2 conditions was CBM administration, scoring, and results displays. Teachers in the computer-based Treatment 1 condition were trained in the process of how the CBMs were scored; however, the digital environment supported this task by automating the majority of measurement scoring and graphed the results instantly. This training was conducted to provide a clear understanding of how the scores for each measure are derived and interpreted. Teachers in the Treatment 2 condition were trained in CBM administration, scoring, and graphing results by hand using the traditional paper and pen. Finally, in both treatment conditions, teachers were taught how to interpret the graphic displays of student performance and analyze the error data associated with each measure.

To assure teacher competence of tool use, trainers posed use-case scenarios throughout the session, initially to demonstrate tool function, then to provide guided and independent

practice. Finally scenarios were used to observe and informally evaluate ability to navigate, assign, and make changes in the tool for students. Researchers/trainers frequently checked in verbally to assure understanding, comfort, and recall of Strategic Reader use.

Student training. Participating students were also trained in basic navigation and functions of the digital reading environment, which included the novels, forums, and CBM. Training occurred as a part of classroom instruction, usually with the classroom teacher and researcher teaming to demonstrate and discuss the tool; this occurred during regular classroom time (40-to-55-min sessions). Students were first taught how to use the digital books with reading supports, followed by the forum. They were then introduced to the progress monitoring measures by way of explanation, demonstration, and practice use. For all components of the Strategic Reader, students were allowed and encouraged to experience the computer tool prior to formal instruction/assessment. Using a demonstration site, students were given tasks to complete in a "non-scored" scenario, read a passage, and answer questions with keyboarding, then audio recording. Students were asked to complete additional program tasks, such as listen to text, look up glossary words, use the dictionary, and so on. Teachers then taught students the expectations for Strategic Reader specific to their class. For example, one teacher directed students to begin each class by logging in on the forum and responding to a minimum of three posts about the current novel in the first 5 min. Another teacher set an expectation that all responses to embedded questions needed to be in complete sentences with correct grammar, punctuation, and spelling. Furthermore, teachers were provided enough training to feel comfortable troubleshooting any student challenges. Frequently, students helped one another locate and use features, and navigate the tool. If difficulties arose, a member of the research team was always available to help in solving any student issues with the reading environment, forum, or CBM.

Progress Monitoring

A set of three measures (oral reading fluency, maze, and reciprocal teaching strategies) was taken for each CBM measure in the respective treatment conditions (online and offline). From these initial CBM measures, teachers were able to establish baseline levels and, from there, develop performance goals for each reading measure. Using the baseline mean score and the goal, aim lines indicating desired rate of progress to meet the goals were calculated (by the computer in the Treatment 1 condition and drawn in by hand in the Treatment 2 group). These data allowed for analysis of the rate of growth for each student throughout the study. Once reading in the digital environment started, the CBMs were repeatedly administered. The oral reading fluency and maze measure were administered twice per month and the reciprocal teaching strategies measure was administered at the completion of each novel. Teachers used progress monitoring results during the research study to make instructional decisions. We report pre to post gains on progress monitoring scores and continue to analyze these data in relation to growth over time for reporting in the near future.

Measures

Several assessments with a focus on reading ability were administered before, during, and following use of the Strategic Reader to gauge growth over the 11- to 12-week intervention. Pre- and post-tests using the Gates-MacGinitie (MacGinitie, MacGinitie, Maria, Dreyer, & Hughes, 1999) standardized reading measure were administered to all subjects in both conditions. Progress monitoring using CBM reading measures (oral reading fluency, maze, and reciprocal teaching reading comprehension strategies) was administered regularly throughout the study for student and teacher use in monitoring progress and instructional decision making. In addition, surveys and interviews were conducted with participating students and teachers.

Pre-test of reading ability. Prior to the intervention, students' reading comprehension was measured using the *Gates-MacGinitie Reading Test*, which included vocabulary and comprehension subtests. Researchers administered this measure to students in both conditions during class time prior to use of the Strategic Reader tool. The Gates-MacGinitie Reading Test was selected as it has been shown to have quite reliable results (Cooter, 1989). An added benefit of this choice of measure was that it allows a direct comparison of the efficacy of this intervention with many other interventions in the literature that have also used the Gates-MacGinitie Reading Test (e.g., Dalton et al., 2011).

Post-intervention. At the project conclusion, post-research measures were administered in both research conditions. Reading comprehension was measured post research, again with the Gates-MacGinitie Reading Test. A post-research score was taken for each of the CBMs (oral reading fluency, maze, and reciprocal teaching reading comprehension strategies).

Teachers participated in closing interviews, and students took a closing survey, regarding their experiences. Researchers developed survey and interview questions to identify descriptive indicators of participant understandings, perceptions, and opinions about use of the Strategic Reader. Surveys and interviews were administered to teachers and students by the researchers. Results were compiled for descriptive analysis. Survey questions used a 4-point

Likert-type scale with 1 representing low response and 4 being positive (e.g., *strongly agree, very helpful*).

In addition, project researchers using protocols adapted from previous research conducted classroom observations twice each month. Targeted behaviors for identification included positive/negative interactions with the program, student engagement and affect while using the UDL reading environment, student ability to navigate through the system, user–machine comfort, and use of features without urging. To check and maintain interrater reliability, two researchers observed 10% of the observations, resulting in 87% to 90% agreement. Information from observations was used to coach classroom teachers in use of Strategic Reader and help show relationships between data collected by the tool and instruction or supports use.

Usage tracking. Built into the Strategic Reader tool was an event usage log, a large database designed to log usage. All student and teacher interactions with the tool in both Treatment conditions were centrally logged and available for ongoing analysis by researchers. This database captured user clicks on the functions and features in the tool and thus provided descriptive data on the use of features, strategies, and supports available in the tool. Specifically, we collected student use of the supports and responses to reading questions. For teachers, we collected teacher viewing of student and/or class data, intervention design, and changing of levels within Strategic Reader.

Results

Both quantitative and qualitative data were collected, and thus, a mixed methods approach was used for our data analysis. Although randomization for this study was by teacher, the majority of analyses were at the student level. Traditional *t* tests for differences using the pre- and post-test standardized measures were used for the quantitative data. The qualitative data were coded by themes (computer experience, reading skills, forum dialogues) and then sorted into categories (e.g., navigation, supports, comfort level). Three researchers coded these data with a 20% overlap; reliability among coders was 93%. All analyses were conducted both on the total sample and the subsample of students with disabilities.

Teacher Change

Our first research question related to teachers and their instruction during the intervention, and the electronic usage log in the Strategic Reader allowed us to analyze teacher viewing frequency and use of the tool in both conditions. An analysis of visits to the "view results" section on the teacher's side of the tool revealed the number of times teachers changed supports or strategies for student use.

Table 2. Teacher Use of Progress Monitoring Data and Supports.

Teacher data use	Treatment 1 condition (n = 5)	Treatment 2 condition (n = 5)
Viewed student data	372	105
Designed interventions	67	12
Modified student supports	86	2

Researchers counted the number of interventions developed and entered for students by teachers, and interviewed teachers about the use of this area of the tool and how they used it. To analyze teachers' use of the progress monitoring data in the Treatment 2 condition (progress monitoring offline), we periodically reviewed student graphs, housed in teacher's classrooms, and queried them during the interview. Our analysis of data included whether the teachers had updated student graphs, designed interventions, and wrote comments about student progress. Teachers in the Treatment 1 condition viewed and designed interventions over 3 times more frequently than the Treatment 2 teachers. Table 2 highlights the differences in teacher use of the progress monitoring data and supports. For example, teachers in the Treatment 1 condition (n = 5) viewed student data 372 times, while teachers in the Treatment 2 condition (n = 5) only viewed student data 105 times. Moreover, teachers in the Treatment 1 condition designed interventions 67 times, while those in the Treatment 2 condition designed 12.

Student Change

Results for all participating students on Gates-MacGinitie pre- to post-scores had a large and statistically significant increase at the .01 level (including students with and without disabilities). Specifically, student scores increased by 4.89% in the online treatment condition and by 4.31% in the offline treatment condition. Changes in score results for both conditions are shown below in Table 3.

The paramount result of the study, directly addressing our second research question (Is the technology-based approach to monitor student performance in reading more effective in improving student performance on standards-based measures of reading comprehension?) is that students with LDs experienced large benefits from the online versus offline CBM experience. Results from the Gates-MagGinitie indicate that the students with LDs who were in the online treatment group had an increase of more than 10% (10.4%) from pre to post experience, which was statistically significant at the .05 level. In contrast, students with LDs in the offline group increased by 6.58%, which was a positive change; however, it was not statistically significant. Changes in score results for both conditions for the student population with

Table 3. Pre–Post Gates.

Participants and condition	*n*	*M* pre Gates	*M* post Gates	Change	% Change	*t* stat	*p* value
All students							
T1 (online)	105	47.71	50.05	2.33	4.89	2.59	.011
T2 (offline)	98	68.01	70.94	2.93	4.31	2.62	.01
Students with learning disabilities							
T1 (online)	33	38.18	42.15	3.97	10.40	2.36	.025
T2 (offline)	22	53.91	57.45	3.55	6.58	1.32	.2

LDs are then shown in the accompanying Table 3 section "Students With Learning Disabilities."

To summarize the quantitative results, students, particularly those with disabilities, who had *online* progress monitoring in the Strategic Reader (in the Treatment 1 condition) showed greater growth on reading measures than those who used the same tool without online measures. Moreover, this difference between students' performance online versus offline was larger and statistically significant for students with disabilities: Only in the online project monitoring condition did students with disabilities show a statistically significant increase in scores (see Table 3) that provides a summary of scores for the entire sample (online and offline conditions combined), as well as each condition for Treatment 1 and Treatment 2, and ability.

Student survey data were analyzed for all participants. When asked about their own reading skills, students with disabilities had a mean response of 3.0, *SD* 0.47 (scale of 1–4, 1 = *low* and 4 = *highest*), indicating they *felt* their reading skills improved substantially as a result of using Strategic Reader. This self-report information is associated with student's standardized achievement pre- to post-test improvements. Students with disabilities also reported to be both more engaged by (and with) many aspects of the Strategic Reader. For example, when students were asked to rate their experience having to respond to the embedded reading strategy questions, students with disabilities had a mean score of 3.10, *SD* 0.57, versus regular education students mean of 2.35, *SD* 0.84 (*t* stat on the 0.75 difference of $t = 2.79$). Overall, students with and without disabilities, regardless of treatment condition, felt that the use of Strategic Reader to read and respond to novels and improve their reading was helpful with a mean score of 2.47, *SD* 0.79.

When analyzing student responses to the supports and scaffolds available in the Strategic Reader, most students were positive overall about those features. Students with disabilities in each condition reported to both *use* and *find helpful* the supports of the animated pedagogical agents (*M* score 2.2, *SD* 0.92), passages read out loud (*M* score 3, *SD* 1.25), sentence starters (*M* score 2.88, *SD* .99), and story highlighting (*M* score 3.18, *SD* 0.98).

With regard to progress monitoring, the reported experiences of both treatment condition participants varied substantially. Overall, students with and without disabilities in the Treatment 1 condition had no strong opinion regarding taking the measures (maze, *M* score 2.87, *SD* 0.89; read aloud, *M* score 2.39, *SD* 1.05). During the interview process with these students, we found that initially, they did not understand *why* they were taking the measures. During the early steps of the intervention, they reported that once they were taught how to read the graphs and think about their reading skills in relation to their performance scores, they were more interested in taking the measures and looking at their scores. Teachers reported observing students attending to their graphs and work logs both during teacher–student conferencing sessions and independently. However, the Treatment 2 condition students (offline progress monitoring) reported they did not make a connection between the measures they were taking twice per month and their work in the Strategic Reader tool. Teachers and students reported that they rarely, if ever, viewed or shared the graphic displays of their performance scores. Many teachers noted it was too difficult to access the actual file folders with the graphs on them for all the students and have discussions. These findings directly addressed our research question, concerning the efficiency and effectiveness of the online versus offline implementation of Strategic Reader tool.

Discussion

This research examined the effectiveness of embedding CBM directly into a UDL digital environment with supports for teacher instructional decision making and to analyze the impact on all students, particularly on those with LDs. Research results from this experimental study demonstrate (a) the effectiveness of the general approach of using technology to combine UDL and CBMs for students with LDs and (b) the significant potential of UDL and CBMs for improving reading comprehension for all students.

Interventions designed during instruction were based on student needs and teacher strengths. All participating teachers were working with the same web-based tool and interpreting the same curriculum-based measures; however, learning exercises and activities varied across project classrooms based on teacher interpretation of the progress monitoring information and student needs. This was one of the most encouraging

aspects of the study: The built-in flexibility of the Strategic Reader leads teachers to create tailored interventions for individuals in their classrooms. The variety of observed effective approaches suggests that there was indeed synergy between the relatively prescriptive principles of CBM and flexible principles of UDL, as embodied in the design of the Strategic Reader. This finding underscores both the importance and potential power of differentiated implementation of Strategic Reader based on a teacher's expertise and intuition.

There were many examples of how teachers designed interventions as a result of using the Strategic Reader. Each example demonstrates how the various parts of Strategic Reader in flexible adaptation work together in a measurement-driven approach. For instance, one participating teacher used the oral reading fluency and maze to inform both whole-class and student-specific instruction. This teacher then highlighted school-wide reading fluency difficulties and successfully advocated for focused reading instruction time by restructuring the school day the following school year. In a second example, a teacher was able to execute individualized instruction despite having a class size of 35. This teacher used students' CBM data and reciprocal teaching reading strategy responses as the basis for teacher-to-student conferences, to inform whole-class instruction and engage peer-to-peer mentoring. In addition, this teacher used video production (screen writing, storyboarding, and reenacting scenes from the novel) as both an engaging learning activity that encouraged rereading and an avenue to express comprehension. A third example highlights how one teacher used feedback from the Strategic Reader as a tool for engagement. Not only did this teacher teach and practice the reciprocal teaching strategies across different content areas (e.g., ELA, social studies, science) and different contexts (e.g., in the classroom, while reading the novel online, and in discussion forums), but she also engaged and sustained learner motivation by providing a choice of content and context for guided practice and feedback.

Limitations

Although the results of this study are promising, there are limitations to note. First, there was an uneven distribution of participants across grades. There were more sixth-grade participants than seventh- and eighth-grade. Next, the two treatment groups were not equivalent based on pre-test results. Although, this was a result of random assignment to treatment group prior to this assessment. Finally, instructional conditions varied slightly across all classrooms for how the novels were addressed within the classroom's curriculum. For example, all classrooms completed reading two novels from the Strategic Reader. Some teachers had units for the novels as part of their ELA curriculum, while other teachers use the novels as additional class readings.

Participating students, including those with disabilities, were provided with a highly responsive learning environment that was designed to reduce barriers and enhance supports for learning on an individual basis. Supports and scaffolds were guided by information from accurate and timely progress monitoring to improve reading comprehension. The overall impact was improved access, participation, and progress in achieving standards-based results.

This study also shows that technology can help the teacher do his or her job more effectively by extending his or her reach to more students more of the time. Teachers in the online treatment condition had easy access to student-specific reading comprehension data, which in turn enabled them to make curricular changes more easily and in a more timely manner than they otherwise could have (e.g., data analysis, scoring, and graphing by hand). Ultimately, teachers could focus on the teaching episode versus spending their time trying to organize and manage the data. In addition, the visual aspect of the graphed data, although not a main emphasis of this study, assisted teachers in easily reading and analyzing data to determine whether changes needed to be made. The same visual aspect served a dual role of enabling students to be self-reflective on their work, potentially enhancing their motivation.

The researchers consider this an initial proof of concept of this treatment package to support reading comprehension. In future research, we recognize the need to control more classroom variables when using Strategic Reader to more explicitly attribute change in reading performance.

The real innovation in the Strategic Reader, then, is not the technology per se but rather *how* teachers effectively use Strategic Reader to spark interactive and meaningful learning. The success of the Strategic Reader project may help provide guidance for future policies, along with having especially innovative potential for learning materials for students with disabilities. Reading environments such as this one that leverage new technologies to support teachers can help ensure that every student is highly engaged in meaningful learning and practice that optimize his or her development as a skillful student.

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