Nonfiction Reading Comprehension in Middle School: Exploring in Interactive Software Approach

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The struggles of students in the United States to comprehend non-fiction science text are well documented. Middle school students, in particular, have minimal instruction in comprehending nonfiction and flounder on assessments. This article describes the development process of the Readorium software, an interactive web-based program being developed to assist students with comprehension of science text. The program incorporates research-based recommendations for effective reading comprehension suggested by the Institute of Education Science (IES). Efforts to turn the IES recommendations into a coherent software product that motivates learners are described, as is the process of incorporating student and teacher feedback to improve the usability of the product. Preliminary results suggest that the program operates efficiently, motivates students, and may substantially impact student comprehension of science text.

Introduction

National measures of student achievement in reading – particularly in the area of nonfiction texts – suggest that achievement gaps persist and schools are not meeting the expectations of business leaders, politicians, parents, and teachers (Vanneman, Hamilton, Baldwin Anderson, & Rahman, 2009). As recently as 2011, 66% of eighth grade students scored below the proficiency level on the National Assessment of Educational Progress (NAEP) reading assessment (National Center for Education Statistics, 2012). A particular area of concern regards the ability of students to

comprehend text in the area of science. The 68% of U.S. students who scored below the proficient level on the 2011 NAEP Science Achievement test provides evidence of the struggles of the United States educational system in effectively teaching science. The U.S. also fared poorly on another large-scale comparative international science study. The U.S. ranked 13th out of 33 countries in the 2009 Program for International Student Assessment (PISA) (Fleischman, Hopstock, Pelczar, & Shelley, 2010).

Students who struggle with basic literacy skills have difficulty performing well in school and risk becoming disaffected, often dropping out of school. According to the Institute of Education Sciences (IES) High School Dropout Rate Report's most recent information, only about 75% of public high school freshmen students graduate in four years (Chapman, Laird, Ifill, & KewalRamani, 2011). Compared to high school graduates, "dropouts" will earn less income over their lifetime, have more health problems, and are more likely to be institutionalized (Pleis, Ward, & Lucas, 2010). Beyond the cost to these students, there is a significant cost to the nation, estimated at $240,000 per dropout over their lifetimes, due to lower tax contributions, higher Medicaid and Medicare expenses, and other costs related to criminal activity and welfare (Levin & Belfield, 2007).

Although there have been major breakthroughs in research on the most effective ways to teach comprehension, many teachers, especially in the intermediate and upper grades, continue to lack the training and/or resources, to implement these techniques (Biancarosa & Snow, 2004; Biancarosa & Snow, 2006). Consequently, early reading difficulties tend to become exacerbated over time as students encounter increasingly challenging content material. Snow (2002) suggests that while some older students still struggle with decoding, many more have difficulty constructing

meaning from text. Struggling readers find comprehending nonfiction text especially challenging due to the specialized vocabulary and the new concepts presented (Biancarosa & Snow, 2004; Biancarosa & Snow, 2006).

Mason and Hedin (2011) discuss four specific characteristics of expository text (including science text) that make comprehension particularly challenging for struggling readers. These areas include: complexity of text structure, conceptual density, technical vocabulary and the necessity of prior knowledge to comprehend new material. Consequently, students find science texts too difficult and not relevant to themselves. They report that texts are boring and turn them off to reading. Teachers often compensate by teaching the content in class, rather than depending on the textbook (Johnson & Zabrucky, 2011).

Since the release of the National Reading Panel's (2000) findings on the effectiveness of various approaches to reading instruction, significant research has focused on how to implement many of the National Reading Panel's (NRP) recommendations. One of the central areas of focus of the NRP was "Text Comprehension Instruction" (NRP, Chapter 4, 2000). Their findings suggested that "strategies" rather than "drill" were most effective in improving reading comprehension (NRP, 2000; Duffy, 1993). The findings also suggested that teaching students to acquire and use strategies may require altering traditional approaches to strategy instruction (NRP, 2000, p. 4-47). Interestingly, the NRP defined computer technology in reading instruction as one of the "most important" research areas in the field (NRP, 2000, p.6-9).

Educational technology and student engagement

Over the last decade, there have been many studies focused on the use of technology in every phase of classroom instruction. Research by Ahmet, Bulent, & Cemalettin (2011)

suggests that technology possesses the potential for improving instruction in the classroom. This research indicates that most students report that technology directly improves their learning because it allows them to learn by doing, discovering, and interacting (Ahmet et al., 2011). As such, the promise of effective use of educational technology is that it can increase student achievement by improving student engagement. This conclusion supports suggestions made by the NRP in their 2000 report in the area of reading instruction. Additionally, work by Neuman (2001) noted that students who fail at reading lacked both the motivation and self-confidence to learn. This is consistent with research that suggests that when students interact with technology-based text, their scores in comprehension, vocabulary, and fluency improve (Hansen, 2005; Rochelle, Pea, Gordon, & Means, 2000).

There is little doubt that motivation plays a central role in the observed reading comprehension improvements. Mouza (2005), for example, found that computer use promoted a more generalized increase in persistence and motivation. Other work suggests that elementary and middle school students report an increased sense of ownership of their classroom experience when instruction includes technology (Speaker, 2004). These findings are important as schools transition from traditional print to more multimedia-based materials. Evidence suggests that there has been a significant rise in every type of electronic text over the last ten years and that the trend will only continue (Jeffs, Behrmann, & Bannan-Ritland, 2006). Anderson-Inman & Horney (2007) report that virtually all text material in schools today as well as in the future will be available in electronic form (p. 159).

Best practices in adolescent literacy instruction

A recent Institute of Education Sciences (IES) practice guide presents a series of recommendations for efforts to improve adolescent literacy (Kamil, Borman, Dole, Kral, Salinger, and Torgesen, 2008). IES practice guides are subjected to extensive external peer review and can reasonably be regarded as the gold standard source for best practices in the topic area. The five recommendations for effective programs to increase adolescent literacy are as follows: (i) provide explicit vocabulary instruction, (ii) provide direct and explicit comprehension instruction, (iii) provide opportunities for extended discussion of text meaning and interpretation, (iv) increase student motivation and engagement in literacy learning and (v) make available intensive and individualized interventions for struggling readers.

The *Readorium* approach

Readorium is a web-based software product that has been developed to help struggling middle school students comprehend nonfiction text in the area of science. This paper describes the efforts of the *Readorium* development team to implement the five features of effective adolescent literacy practices in an engaging and easy to use software product. In particular, the first phase of the research that was conducted to inform the development of the *Readorium* software is described herein.

The first phase of the development of *Readorium* focused on creating a prototype and gathering student and teacher feedback to improve the usability and usefulness of the software. Descriptive statistics computed based on student and teacher feedback are presented herein, and the steps taken by the research team to incorporate this feedback into the software are described. The results presented are based mainly on individual and small group student and teacher interviews. A somewhat more intensive case study of an individual student is presented. Because the focus of the

initial research was on software development, reading comprehension outcome measures were obtained only for students using *Readorium* and not for control group students. As such, we are unable to make strong claims about the efficacy of the *Readorium* software at the present time. However, there is some evidence that students using *Readorium* were able to exceed the expected comprehension gains using an externally validated instrument for measuring reading comprehension in online environments. The research team is in the process of collecting data from a randomized design with control group subjects. The results of this data collection project will be presented in a future publication and will provide much better evidence of the efficacy of the *Readorium* program.

The *Readorium* conceptual framework

There are literally hundreds of software options available for schools for literacy instruction. In 2005 alone, one study estimated that there were anywhere between "300 pieces of software and more than 500 instructional websites available or on the market aimed at improving primary or early secondary reading skills" (Khan & Gorard, 2005). The *Readorium* conceptual framework differentiates itself from typical reading comprehension programs by systematizing strategy teaching, individualizing both the content level and support students receive based on their progress, and by providing a multi-faceted motivational system.

In a typical school, middle school students who are at-risk for reading below grade-level, do not receive targeted instruction in comprehending nonfiction text. The *Readorium* program, which is funded through the support of a USDOE Small Business Innovation Research (SBIR) Grant, explicitly teaches struggling readers scientifically-researched strategies to help them understand nonfiction text in the area of

science. The paragraphs below describe the manner in which the five recommendations in the IES practice guide (Kamil, et al., 2008) have been implemented in *Readorium*.

Provide explicit vocabulary instruction. Readorium's content vocabulary cards, presented at the beginning of every article that children read through the software, are also embedded in the text, giving students repeated exposure to new words. Each card contains an audio definition, a written explanation, a multimedia example, and a question. Cards can be accessed later for review. Specific strategy lessons focus on using context clues to figure out new word meanings. Missing words in the text for students to fill-in require an understanding of how to use the new content vocabulary in context. "Lightning Rounds" (content-based questions) give students practice in using new terms. In addition, content vocabulary games, embedded in each topic strand and in the Emporium, (the motivational center of the program) provide additional content vocabulary practice in an engaging format.

Provide direction and explicit comprehension instruction. Each topic, or strand, is paired with a research-based reading strategy, such as inferring or visualizing (Pearson, David, Dole, Duffy, & Roehler, 1992). When students encounter a new strategy, they participate in an interactive "master avatar lesson" on the strategy. The e-tutor (guide) then directs the student through each strand's seven articles, demonstrating the use of strategic thinking to make sense of the text. As the student progresses through the articles, the guide uses the "gradual release of responsibility model" (Harvey, 1998), incrementally increasing the student's independent strategic thinking, while decreasing support. Related comprehension questions are paired with the strand's strategy. Students, who need support to answer correctly, get hints that remind them how to use strategic thinking to answer questions.

Provide opportunities for extended discussion of text meaning and interpretation. Readorium contains a "Teacher Resource

Center" with classroom lessons that complement the science material embedded in the program. These include strand templates with discussion ideas that students can use with peers in a literature circle type format, so that students who read the same topic strand can explore what they learn in greater depth together.

Increase student motivation and engagement in literacy learning. Kamil, et al., (2008) define motivation and engagement in the context of literacy instruction as follows. *Motivation* is defined as a "reason to become involved in a task or activity," and *engagement* is defined as the "processing of text deeply through use of strategies, thought processes, and prior knowledge." Students who have difficulty reading are not inclined to read, and nonfiction text, which is more challenging than fiction text, is less likely to entice struggling readers.

The reward system, a prominent feature of *Readorium*, enables students to earn virtual dollars and medals for completing a variety of comprehension tasks. The reward center of the program, the *Readorium Emporium*, contains various engaging options. There students can choose "earning by learning" activities and earn additional awards through correctly answering questions about science videos, special interest articles, and by participating in content vocabulary games. The Emporium also has a Game Room and a Hall of Fame where students are featured for various achievements such as membership in the *Readorium Millionaire's Club*.

Student autonomy is built into the program based on research that supports choice as motivation for reading (Guthrie & Wigfield, 2000). Although *Readorium* enables teachers to assign topics to students, most teachers allowed students to choose topics based on their interests. When students find text to be relevant, they tend to be more engaged (Vansteenkiste, Lens, & Deci, 2006). In order to

interest students in topics that may seem less immediate to their experiences, articles were written with their "lens" in mind. Strategy lessons and strand introductions use relevant examples, images, and analogies to help students make connections between new science concepts and their background experiences. Humor in the guide scripts encourages maintained interest in the text, while interactive program features help students remain engaged while reading.

Since students are automatically and continually presented with text at their own reading level, the program inspires confidence by helping them to be successful. Struggling readers are not stigmatized when they use *Readorium* because they are not identified as such by their peers. Rather than reading different texts than their peers, or participating in intervention classes or programs, these students read the same content, but at their own reading level, and answer the same comprehension questions as their classroom peers. In the long term, anonymity, coupled with successful reading experiences, can motivate struggling students to persevere with challenging text (Dalton & Proctor, 2007).

Make available intensive and individualized interventions for struggling readers. To foster student learning and independence, topics are divided into demonstration and guided practice articles followed by five independent articles. In the demonstration article, the guide gives direct instruction in strategic thinking and models the application of the particular learning strategy. In the guided practice article, the guide provides some support to help students answer questions. During independent practice, the students "fly solo," and seek help from the guide in the form of increasingly pinpointed hints to answer questions, as needed. In order to make text accessible to all students, the students' initial reading level establishes their initial grade level placement. Articles with the same concepts, content vocabulary, and

structure are written at 12 different readability levels from 3.0 to 9.0, at half-year incremental gains. After initial placement, the reading level of each article presented is determined by the amount of support the student needed to answer questions successfully in the previous article. In addition, *Readorium* scaffolds instruction so that struggling students are presented with additional supports to foster engagement with text. These include cloze technique features and "lightning round" questions, which ensure that students maintain active focus as they read. Common real-life examples that illustrate scientific concepts are included to help students make connections. Students are also given multiple opportunities to answer questions correctly so they can focus on mastering comprehension strategies.

Sample

The research was conducted in two phases with two different samples of teachers and students. The objective of the first phase was to develop a prototype of the software and collect feedback on the functionality and usability of the prototype. The objective of the second phase of the research was two-fold. The main goal was to determine the program's feasibility and usability. Would the features work? Could teachers integrate it in the classroom? How would students respond to the program? Would the "motivating features" be effective for students? The secondary purpose was to determine if the program showed promise in increasing students' reading comprehension.

Phase 1 of the research involved 80 middle school students from four classrooms in four New Jersey school districts. The districts involved had a wide range of demographic profiles. To illustrate, districts ranged from 23% minority students and 7% of students eligible for free or

reduced lunch to 88% minority students and 52 % eligible for free or reduced lunch.

Phase 2 of the research involved 200 sixth grade students from 15 classrooms in 6 school districts in New Jersey and Connecticut. Table 1 summarizes racial/ethnic distributions, subsidized lunch status and Limited English Proficient (LEP) status of the participating districts.

Procedures, measures and data sources

In phase 1 of the research students were asked to choose from 19 science strands (topics) and teachers were trained to oversee the program and integrate it into their classroom practices. Students and teachers utilized the program over a six week period in the fall of 2010. Since *Readorium* is web-based, students could also access the program outside of the classroom during the six week testing period. All information in phase I was collected via short individual or small group interviews with teachers and students.

The protocol for the phase 2 study involved students using the program for two class periods a week, and one to two hours at home if they had Internet access, for six weeks, between April and June 2012. As classes proceeded with the program, *Readorium* staff was available by email and phone to assist with concerns.

In phase 2 a variety of methods and measures were used to collect data. Students provided feedback through the software interface in the form of strand-based reflection sheets (regarding content, strategies and article features) and online "Cash for Creativity" feature that earned them real dollars for original ideas that could be considered for incorporation in the next *Readorium* iteration. Also, students completed an online survey at the completion of participation that asked questions about program features, views about reading before and after using *Readorium*, and solicited suggestions for further development of the program.

Additionally, a small subset of students was selected to provide qualitative feedback through informal interviews.

Teachers completed pre and post surveys regarding their students' reading competence, use of strategies, and reading

Table 1
Percent of School Enrollment by Race, Subsidized Lunch and Limited English Proficiency (2010-2011)

	Ethnicity								
District	White	Black	Hispanic or Latino	Asian	Native or Hawaiian American	Two or More Ethnicities	Free and/or Reduced Lunch	Limited English Proficiency	Enrollment (Total)
A	66.6	2.9	8.5	21	0.8	0.2	4.6	1.8	8909
B	12.5	43.8	28.2	13	0.2	0	32.1	4.1	3938
C	13.6	29.3	50.8	5.9	0.4	0	52.1	6.7	4880
D	60.8	3.5	19	15	0.1	1.6	10.4	1.2	1697
E	35.5	3.6	20.8	38.8	0.2	1.1	11.7	4.5	1738
F	92.8	0.8	3.3	2.5	0.1	0.5	1.5	0.1	968

Sources: New Jersey Department of Education Enrollment Data 2010-2011
Connecticut State Department of Education – Connecticut Education Data and Research

behaviors. Some teachers also sent additional discursive comments.

Student reading comprehension was measured both immediately prior to using the *Readorium* program (pretest) and after completion of the six week field test period. Reading comprehension was assessed by using the *Diagnostic Online Reading Assessment* (DORA), developed by the Let's Go Learn company of Kensington, CA. The DORA consists of eight subtests in areas such as phonics, word recognition and vocabulary (Let's Go Learn, 2013). The content validity of the DORA was verified by Dr. Richard McCallum, past director of the Cal Reads reading program at UC-Berkeley. Its criterion validity has also been tested, and high correlations (ranging from 0.60 to 0.90) were obtained between scores on the DORA instrument and paper and pencil administered one-on-one assessments as part of the Cal Reads program. High correlations (above 0.90) were also obtained between relevant DORA subtests and nationally normed paper and pencil assessments such as Woodcock Word Attack.

Reliability (as measured by Cronbach's alpha) was computed for all DORA subtests using a sample of over 17,000 students in grades K-12 from six school districts in four U.S. states. Reliability was over .70 for all subscales except phonemic awareness and above .89 for six of the nine subscales.

Results

We begin this section with a short case study of "James", a 6th grade student who lives in a multi-ethnic urban community. James' science teacher described him as an unmotivated student – "a good kid" who was not interested in "paper and pencil" work, but who was also "not lacking in intelligence." His teacher noted that James's family gave him love and support, but not about academics. It was his

brother, not his parents, who attended James's school conferences. James was a participant in the phase 2 *Readorium* study.

James's science teacher noted that during the six week *Readorium* trial James initiated doing academic work for the first time. He was highly motivated by the program and, "got a tremendous amount accomplished." He not only completed *Readorium* assignments but also went "above and beyond them." He was excited to use *Readorium* and to discuss the science topics he had encountered in *Readorium* with classmates. James's social studies teacher also noticed a change in his attitude – he was now completing work and "had made a turnaround."

James's scores on the DORA assessment showed a gain of about three years. According to his science teacher, James "might not have gone up a full three years in comprehension during the test period" but indicated that the gain was "not far off."

In the post field-test interview, James said that although he wanted to become a "pro football player, not a scientist," *Readorium* helped him to enjoy science more. "Science was easier with *Readorium*. I like it better because I understand it better. Reading is easier for me."

James talked about the program features that motivated him. "*Readorium* is better than regular text because in regular text there are no characters to explain." (In *Readorium* guides are used to explain content.) Content vocabulary cards were "challenging, but they helped [him] when [he] re-read the articles." He also found the comprehension questions difficult, but "the hints were helpful because they told [him] where to reread." James was also able to transfer his new skills to comprehending other text. "Using *Readorium* helps me with other text because it is easier to remember what to do to understand."

Additional phase 2 results

Regarding *Readorium's* usability and feasibility, 70% of students agreed that *Readorium's* directions were clear and 74% felt the program was easy to use. Teachers agreed that the structure of the site was easy to navigate. They also were able to integrate *Readorium* into their classroom practices by assigning it for a certain number of periods per week and working with small groups while others worked on *Readorium*. The student reporting system was used by teachers to assign homework and to group students according to their needs. The rest of the results of student and teacher feedback is presented broken down by the five features of the *Readorium* program that align with the five features of effective adolescent literacy programs described in Kamil, et. al. (2008).

Vocabulary. Feedback on the vocabulary features was consistent. Forty-nine percent of the students reported that the vocabulary cards enabled them to learn new words, and 38% said the cards helped them to understand the articles. Similarly, lightning rounds helped 38% of the students to understand text and 45% said missing words helped them understand text.

Strategy Instruction.

The feedback on comprehension instruction varied by feature. Strategy lessons helped 60% of the students understand text. Comprehension questions challenged 47% to think about what they read and 21% agreed that the questions helped them understand what they read. Hints helped 56% understand what the questions were asking and/or helped them to find the place in the text to re-read to find answers.

Individualized Interventions.

Feedback on interventions designed for the struggling students varied. Eighty percent of the students, all of whom were not aware that they were reading text at different levels, reported that the text was easy to read. With regard to understanding text, 38% of the students said guides' hints helped, and 60% agreed that the strategy lessons helped. However, 62% felt the guides still talked too long. Teachers noted that the guide support for reading strategies helped ensure that students could use the strategies. About half of the students felt missing words and lightning rounds kept them focused on the text.

Features to motivate and engage students.

The extrinsic reward system provided incentives for many students. They enjoyed the competition to become a member of the Millionaire's Club: half the students who accessed that feature were interested to see who was winning; 30% wanted to be on the list and 30% claimed they wanted to work harder to be a "millionaire".

Teachers felt that the Emporium was a great incentive and that incentives motivated their students. Seventy-five percent of the students accessed the Emporium, where the most popular choices were the Hall of Fame (62%) and the Games (55%). The "Earning by Learning": features, e.g., special interest articles and videos were less popular (35% and 23%) This data will inform the next iteration, e.g., students will not have to "pay" for Earning by Learning activities.

Student choice, an intrinsic incentive, was an option for 81% of the students. Although they were not directly asked about the impact of choice, 57% agreed that *Readorium* was fun to use and 54% agreed that it was interesting. Some students also suggested topics to their peers.

Students' self-reports indicated that many (like James) felt that *Readorium* was motivating and enhanced their understanding of text. Two-thirds of the students reported

that they understand science text better, and 61% agreed that they understand what they read (in general) better. Forty-two percent indicated that they apply the reading strategies when they read other texts. When asked about their feelings about reading, 37% said that they enjoyed reading more after using *Readorium* (36% said they always liked to read).

Preliminary evidence of efficacy in increasing comprehension

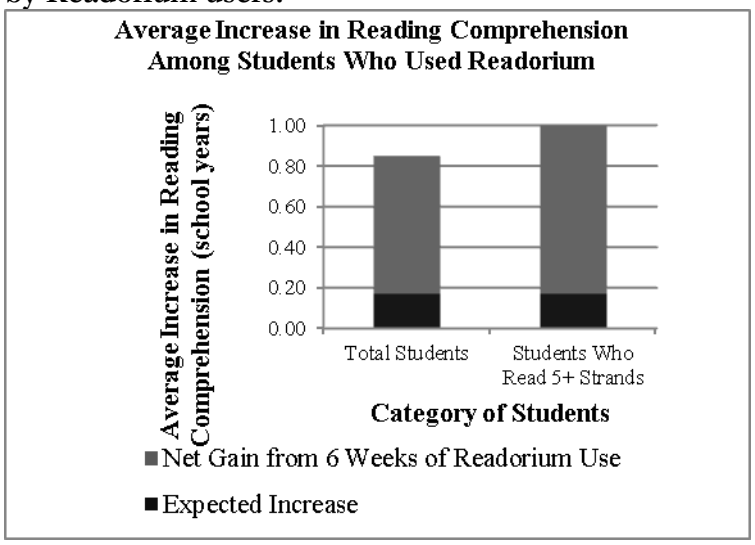
Readorium's impact on comprehension will be more rigorously evaluated in the context of a randomized trial currently ongoing. However, we present in this section some preliminary evidence of impact on comprehension outcomes as measured by the DORA. DORA score reports allow scaling of scores in terms of "grade level increases" or "one year expected gains". The expected gain over the course of the six week trial period is 0.17. The research team hypothesized that students, on average, would exceed the expected .17 year gain for a 6-week period on the pre and posttest administrations of the DORA and that there would be some variability related to the number of strands completed. As summarized in Table 2, the average net gain for the sample was .68 above the expected increase.

Table 2
Reading Outcomes: Average Increase in Reading Comprehension in School Years

Student Participation Category	N	Expected Increase	Actual Increase	Net Gain
Total	165	0.17	0.85	0.68
Read 5 or More Strands	72	0.17	1	0.83
Read 4 or Less Strands	93	0.17	0.7	0.53

Those who completed 5 or more strands were, on average, .83 over the expected increase, while those who completed 4 or less strands, but had completed strategy lessons, had a net gain of .53 years above the expected increase. These results are summarized graphically in Figure 1.

Figure 1
Expected increase in comprehension scores over 6 weeks as compared to the increase actually experienced by Readorium users.



Discussion

Preliminary data demonstrated the potential for *Readorium* to improve nonfiction reading comprehension in science. Comprehension scores were higher than expected for the six-week period for *Readorium* users, with a greater increase for students who read five or more strands. Descriptive feedback from students and teachers was generally positive, and the

software was redesigned to incorporate teacher and student suggestions.

The instructional implications for *Readorium* are numerous. For field testing purposes, student participation in *Readorium* has been limited to two class sessions per week and unlimited home use for a six week period. However, Readorium is designed to be implemented in a variety of settings for various student grouping formats. The program can be integrated into existing language arts and content area practices and/or used for intervention with students who struggle with nonfiction text. Teachers can differentiate instruction by rotating students through *Readorium* stations, while meeting with small groups with similar needs. The program provides a full complement of paper and pencil resources to support online comprehension instruction. Possible venues for struggling students are intervention or basic skills classes, after school and summer school programs, as well as enrichment programs for advanced lower grade students.

Based on the results of the initial field test, the program's features were revamped to further enhance its usability and to increase student motivation. This includes strategy raps, videos and game-like challenges, as well as shorter, more interactive guided lessons, additional content and an enhanced motivational system. Also included is a Teacher Resource Center with in-depth student achievement data and downloadable instructional packets for differentiating instruction. A rigorous study is currently being conducted that will provide better evidence of the efficacy of *Readorium*.

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