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Multi-Touch Tablets, E-Books, and an Emerging Multi-Coding/Multi-Sensory

Theory for Reading Science e-Textbooks: Considering the Struggling Reader

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Abstract

Pavio’s Dual-Coding Theory (1991) and Mayer’s Multimedia Principal (2000) form the foundation for proposing a multi-coding theory centered around Multi-Touch Tablets and the newest generation of e-textbooks to scaffold struggling readers in reading and learning from science textbooks. Using E. O. Wilson’s *Life on Earth: An Introduction* (2012) as a simulation for our essay, we theorize that text, graphics, interactive elements, and audio represent four distinct encoding schemes. Each of these encoding schemes can be used as separate but mutually supportive scaffolds to assist struggling students in reading and learning with science textbooks.

Keywords: struggling reader, multi-sensory, dual-coding, multi-touch tablets, E-textbooks, reading informational textbooks

1. Introduction

The Common Core State Standards (2010) make reading and comprehending informational text central to school and academic success in grades K-12 and beyond. Yet the number of students who lack literacy skills is significant as there are over eight million struggling readers in grades 4–12 in schools across our nation (NCES, 2013). If past trends portend future performance, the reading comprehension difficulties that emerge in grade four exacts greater consequences as the demands in the Common Core to read and understand complex text unfolds in the higher grades (Hirsch, 2003). At issue is how to improve teachers’ instructional routines so the content of science text is more accessible and comprehensible for all students. The Rand Reading Study Group (2002) reported that reading comprehension has been neglected over the past decade, and in particular, reading in the content areas deserves greater attention.

Most students moving from learning-to-read to reading-to-learn have not received sufficient instruction for reading informational texts to adequately prepare them for the challenge of informational text (Duke, 2000; Hirsch, 2003). In what often is referred to as the “fourth-grade slump” (Chall, Jacobs, & Baldwin, 1990), students lack essential reading-to-learn skills, experience reading difficulty, and begin to fall behind even if they previously were reading at grade-level. NAEP (2013) data presents sobering evidence that 65% and 64% of fourth- and eighth-grade students respectively, cannot read grade level materials with understanding. While teaching children to “learn to read” proficiently by third grade is an essential and attainable goal, how to ensure their ability to succeed with informational texts has traditionally received less attention by the scientific community of reading researchers (Hall, 2004). To begin with, studies have shown that students struggle with information text (Best, Floyd, & McNamara, 2008; Braten & Oinstein, 2013; Diakidoy, Stylianou, Karefillidou, & Papageorgiou, 2004). An initial source of that struggle begins with reading fluency as several studies have found that students read informational texts less fluently than they do narrative texts meaning (Author, 2015; Saenz & Fuchs, 2002). Consequently, it cannot be assumed that students read informational text on par with narrative text. Beyond fluency challenges, informational texts can contain events that students may find to be irrelevant and challenging to understand**,** making it essential that teachers use instructional strategies to assist students with comprehension (Beck, McKeown, Sinatra, & Loxterman, 1991; Graesser, 2002).

2. Conceptualizing the Interrelated Components of Reading for Learning in Science (Level 1)

We chose Scarbough's (2001) conceptualization of reading (see Figure 1) to apply to the effective teaching of science, particularly as it relates to language comprehension of science concepts. In this model, language comprehension strands of prior knowledge and vocabulary exemplify the communication and argumentation about scientific ideas that represents the characteristic uses of language defined by the discipline: "controlled experiments," "trends in data," "correlation versus causation" (Duschl, et. al., 2007). Scientific discourse is represented by the language structure and verbal reasoning strands that requires use of special patterns of language, which enable individuals to identify and ask empirical questions, describe epistemic status of an idea (hypothesis, claim, supported theory), critique an idea apart from its author or proponent, and specify types of critiques (e.g., concerns about a claim versus claims about evidence). Students are often challenged because each of these forms of language may require learning new uses of communication. Literacy knowledge is a strand that represents the cognitive capabilities of knowing text structures and how they vary in narrative text sources versus science textbooks and how to use such knowledge to maximize learning and comprehension. It is worthy to note that the strands of word recognition bind together the comprehension strands to construct a strong rope that will support learning.

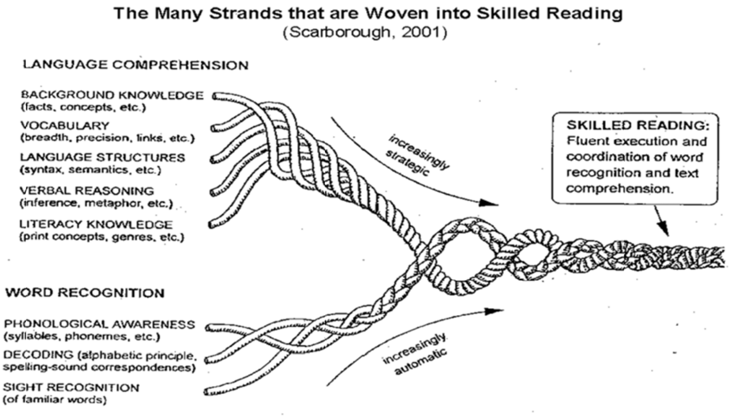


Figure 1. Scarborough's strands of skilled reading

Researchers have noted that the more sensory input channels learners can use in processing information the more likely learning is to occur (Rourke, Ahmad, Collins, Hayman-Abello, Hayman-Abello, & Warriner, 2002). Students today live in a multisensory world where input to the brain through the visual, auditory, kinesthetic and tactile channels is commonplace and thus should readily transfer to enhancing their interaction with science texts and learning science concepts. The technology components of e-textbooks and other devices all have capabilities of presenting science information to students in a multi-input learning manner.

3. Considering the word recognition strand in reading science text (Level 2)

Struggling readers may not have word recognition strands fully constructed (Carlo, August, & Snow, 2005), and as such they will need scaffolded support to make sense of science concepts. It may be that such scaffolding is provided through means other than reading and writing about science concepts, such as hands-on activities (authors, in press), narrative informational texts (authors, in press) listening to and viewing (Cartwright, Marshall, Isaac, & Hodgkiss, 2006), word-play activities that focus on scientific language and multiple meanings, and technology that perhaps can provide such supports in an integrated fashion.

4. Considering the language strand in comprehending science texts (Level 2)

The components of vocabulary and prior knowledge are critical language features that demand special attention due to their influence on learning success both in and out of school. Vocabulary of science content can be viewed as conceptual hooks on which new learning is hung (authors, 2002; authors, in press) and enables students to build prior knowledge through the expansion of their vocabulary represented conceptual hooks. Acquisition of these vocabulary hooks is essential to science content comprehension and continual growth of reading, writing, communicating, learning, and thinking in science.

Many students from backgrounds of poverty, students who struggle with reading, and English language learners (ELL) come to school with vocabularies half the size or less of those of their middle-class classmates (Hart & Risley, 1995; Graves, 2004). Without support for reading and understanding the content of science texts, these students will fall further and further behind in their learning. Vocabularies used in science, time and again denote meanings unlike the general everyday use of a particular word. The meanings are more restrictive and carry the preciseness of concepts represented in the text. For example, *parent* in everyday general language use refers to somebody's mother, father, or legal guardian. However, in a science text of chemical reactions, students would most likely encounter the word *parent* as the starting component in a chemical reaction—the *parent* molecules. Students' understandings of science concepts are inextricably bound to their understanding of the vocabulary used to define and communicate the concepts. Confusion resulting in nonsensical meaning can occur from the multiple usages of familiar words, inhibiting understanding of the scientific usage.

5. The Promise of the Inclusion of Media Input in Comprehension of Science Texts (Level 1)

Mayer's Multimedia Principle (2002, 2009) suggests that media enhances students' learning when instructional messages are presented in a manner congruent with how the human mind operates. Three assumptions gird Mayer's theory. First, humans have multiple routes for processing information consisting of an auditory/verbal and visual/pictorial routes (Paivio, 1991). Secondly, a processing route is limited in the amount of information that can be processed at any given moment (Baddely, 1986, 1999). The third assumption recognizes that people are active learners who process information by forming mental representations. These representations are integrated with their prior knowledge (Kintsch, 1998) and can result in either expansion or refinement of an embellished concept. With these assumptions in place, Mayer suggests that several cognitive processes must take place for meaningful learning to occur in a multimedia environment. Relevant words and images must be selected for processing in working memory. Once selected, these words and images must be arranged into their respective verbal and pictorial models. Finally, these models are integrated with each other and with prior knowledge, thus resulting in comprehension.

Pavio's Dual-Coding Theory also recognizes components of visual and verbal input channels. The Dual-Coding theory posits (1991) that both visual and verbal information are used to represent and make sense of text information. Dual-coding theory (Sadoski & Pavio, 2004, 2014) argues quite convincingly that visual and verbal information are processed differently, using different channels in the brain and creating separate representations for information processed in each channel. The mental codes for these representations are used to organize incoming information that can be acted upon, stored, and retrieved for subsequent use. Both visual and verbal codes can be used when recalling information (Sternberg, 2003). The direct theoretical implication is that students read best when they engage two encoding systems, the text and the graphic/visual.

It is thought that cognitive strategies focus and direct the learners' information processing (Mayer, 1996) and that the depth of understanding is dependent on the richness of the resulting mental image (Ozuro, Dempsey, & McNamara, 2009). A number of authors have assessed the extent to which learner-generated drawings contribute to the development of mental images and subsequent comprehension of content, some with mixed results due to methodological inconsistencies (Leutner, Leopold, & Sumfleth, 2009; Meter & Garner, 2005; Tirre, Manelis, & Leicht, 1997). However, other researchers have found that mental images do contribute to comprehension (Hall, Bailey, & Tillman, 1997; Lesgold, Levin, Shimron, & Guttman, 1979; van Meter, 2001). For example, drawing on the dual-coding theory, Schwamborn, Mayer, Thillmann, Leopold, and Leutner (2010) found that ninth-grade students who generated a drawing of a scientific process scored higher with large effect sizes on measures of comprehension than did students who only read the text describing the process.

6. Text and Visual Coding to Support Students Learning in Science Texts (Level 2)

In a meta-analysis of instructional strategies, enhanced context strategies were shown to be a powerful instructional strategy resulting in large effect sizes ($d = 1.48$) (Schoeder, Scott, Tolson, Tse-Young, & Hsuan, 2007). In addition, the authors also found a significant effect size of $d = .80$ for collaborative learning strategies and noted that e-textbooks provide interactive opportunities for enhanced context that can make learning meaningful for those students who cannot read the text or lack prior knowledge to facilitate understanding of concepts. For example, visual presentations such as volcanic lava, pupa, plasma, etc., become relevant to struggling readers by presenting material in the context of real-world examples and problems. These e-textbooks can bring the real world to students through technology and presentation of concepts in a visual mode that could be beneficial to struggling readers. Furthermore, vocabulary that is unique to the text, such as the example of parent presented earlier, can be visually illustrated to help maximize learning.

7. What is the future of the traditional science textbook? (Level 1)

Advances in publishing (Stern, Aprea, & Ebner, 2003; Trumbo, 1999) have resulted in textbooks that look more like the internet (Leu, 2000), software (Anderson & Slough, 2012) or applications for smart phones. California and Texas typically drive the K-12 textbook market in the United States and have recently launched initiatives to implement digital textbooks as primary or supplemental source material for K-12 instruction (Tomassini, May, 2012). Approximately 22 states are moving in this direction (Hill, 2010) as well. The current administration has endorsed the transition to digital textbooks and engaging all students in digital materials by 2017 (Dylan Scott Key Words: Struggling reader, multi-sensory, dual-coding, multi-touch tablets, E-textbooks, reading informational textbooks).

Textbooks are transitioning to include more graphical information, multi-touch tablets (MTT) and cloud computing. These technology and features open a development window for textbooks that advocate more interactive graphic and visual elements. In this article we are focus on science texts that include features such as hyperlinks, 3-D models, image maps, animations, and videos that profoundly modify *text accessibility* (McTigue & Slough, 2010) for all science learners (Rupley & Slough, 2010). We believe that technology holds considerable potential for all content area textbooks and many of the technology features discussed are applicable to these texts. Such components been reported to support communication; instruction; evaluation, diagnosis, and feedback (Roschell et al., 2007). Furthermore, they have been noted to increase engagement and improve classroom management by encouraging instructional eye contact; logging of voice and video; sharing data using multiple applications (Mock, 2004); and allocating/implementing supplemental material (Hulls, 2005). Text comprehension can be enhanced by such features as 3-D application for improved spatial learning; dynamic content; and speech to text and text to speech features for students with hearing impairments (Mitchell, 2007). MTTs offer the majority of the advantages of a traditional computer with fewer limitations.

One evolving innovative science textbook that takes advantage of the MTT and cloud computing is E. O. Wilson's Life on Earth: An Introduction (2012). An introduction to the resource and the first several chapters are available for downloading on an iPad with iBooks and on a traditional computer with iTunes (this article uses a version downloaded on March 2, 2012). The book is a product of E. O. Wilson Biodiversity Foundation and is being developed over the next two years to take advantage of purported benefits of the MTT, cloud computing, digital publishing in general and the iBooks author tool being offered for free by Apple.

It is likely that each of us has experienced the traditional science text composed of text and typically static graphical elements (Slough, et al. 2010). The MTT adds interactive graphical elements, characteristically with sound and a variety of interactive features that are reminiscent of enactive (learning-by-doing) mode of learning (Bruner, 1961). These interactive/enactive elements extend a traditional text and graphic reading experience to include active participation in the "reading." Examples include things such as simulations, animations, and even internal assessments (see Figures 2 and 3). In particular, animations and assessments include active choices that students' make that enhance their reading experience.

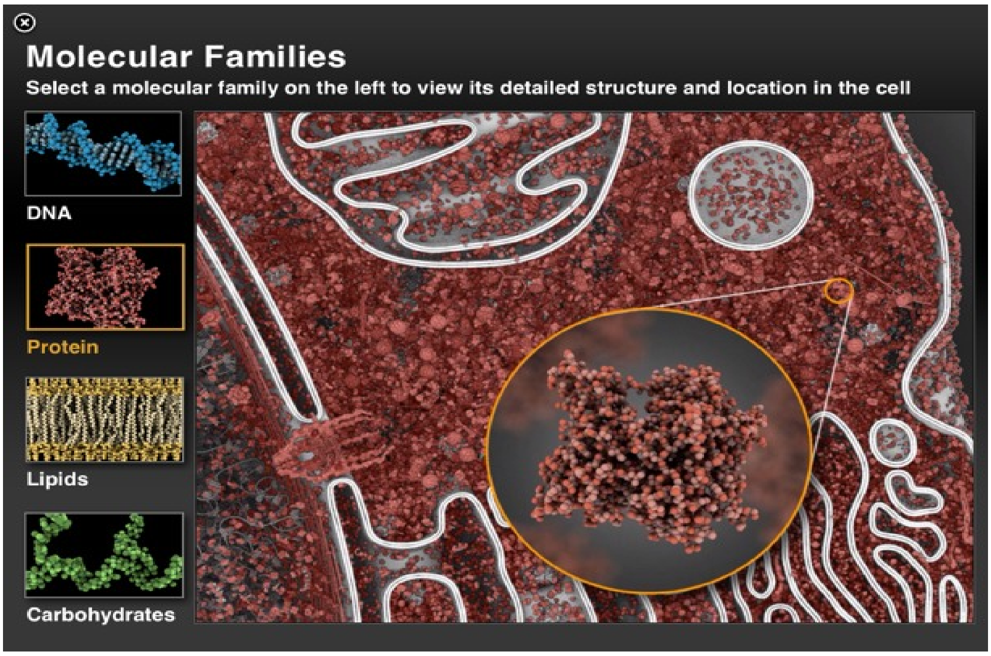
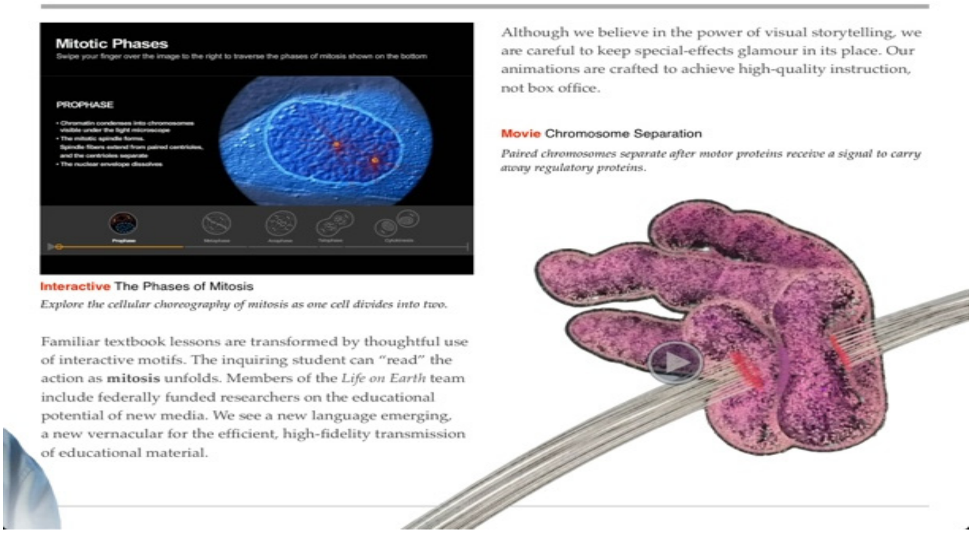


Figure 2. Screenshot of a molecular families animation

An issue endemic to the effective learning from any media is the struggling reader, who experiences difficulty and often lacks the capability of self-pacing and monitoring comprehension. We know from a multitude of syntheses of research (c.f., Beers, 2003; Rex, 2001) and our own direct experiences with struggling readers (Rupley & Slough, 2010; Slough & Rupley, 2010) that they are prone to distraction, lack persistence/focus, become frustrated easily by new tasks, experience difficulty in understanding when text includes unfamiliar concepts or is unconnected to their prior knowledge. There is cautious optimism that the amount and type of interactive graphical elements may ultimately help the struggling reader with the six factors identified in Table 1. This technologically supported instruction may be effective with struggling readers and could result in maintaining a high level of motivation to learn science as it scaffolds their reading and learning of science concepts.



Mitotic Phases

Swipe your finger over the image to the right to traverse the phases of mitosis shown on the bottom

PROPHASE

- Chromatin condenses into chromosomes visible under the light microscope
- The mitotic spindle forms. Spindle fibers extend from paired centrioles, and the centrioles separate
- The nuclear envelope dissolves

Interactive The Phases of Mitosis

Explore the cellular choreography of mitosis as one cell divides into two.

Familiar textbook lessons are transformed by thoughtful use of interactive motifs. The inquiring student can "read" the action as **mitosis** unfolds. Members of the *Life on Earth* team include federally funded researchers on the educational potential of new media. We see a new language emerging, a new vernacular for the efficient, high-fidelity transmission of educational material.

Although we believe in the power of visual storytelling, we are careful to keep special-effects glamour in its place. Our animations are crafted to achieve high-quality instruction, not box office.

Movie Chromosome Separation

Paired chromosomes separate after motor proteins receive a signal to carry away regulatory proteins.

Figure 3. Screenshot showing an interactive animation and a movie

As Life on Earth aptly demonstrates, e-Books add additional encoding schemes that may provide strong and substantial scaffolds for learning for struggling readers. As noted earlier, there is clearly a kinesthetic/interactive/enactive channel that is activated as the student manually manipulates the page, the orientation, and the size of graphics. However, key kinesthetic/interactive components in manipulation are the imbedded and hyperlinked interactive graphical elements, such as simulations and in-text assessments.

Additionally, the MTT and the e-books add an auditory channel that should enhance the learners' engagement and provide huge scaffolding channels for the struggling readers. From simple pronunciation guides, to full audio reading of a highlighted text selection, to audio files, to movies and animations with audio . . . struggling readers clearly have a new coding scheme to help them make sense of their learning experiences with the textbook, improve their reading abilities, and expand their vocabularies. Thus, it is an emerging consensus that perhaps the greatest legacy of the MTT and e-books will not be the beautiful graphics that initially engaged us as designers, but the emergence of Multi-Coding capabilities that become individualized for the struggling readers. Questions that we are encouraging and answers that are awaiting include, "How long will it be before social media is incorporated into the e-textbook? How does reading . . . simply learning…look different when imbedded tools allow interactive dialogues for the creation and exchange of student-generated ideas. Social media is ubiquitously accessible and enabled by a variety of technologies, why not the e-textbook? "

8. Conclusion (Level 1)

There is a whole host of issues that must be acknowledged that will ultimately impact the implementation of the MTT and e-textbooks. Many of these fall within the classroom management realm, technological, resistance to change by teachers and students, integration of pedagogy and technology, and the need for specialized and continuing professional development with these new technologies (Slough & Chamblee, 2007; Bevy & Rupley, 2013). However, the most significant issue facing MTT implementation is how it can be used to improve the learning of struggling readers. The emergence of the e-textbook is the next great technological innovation to hit schools. E. O. Wilson's *Life on Earth: An Introduction* (2012) is a fine example of what can be done with e-textbooks. Students who have traditionally been successful in school will love the technology and will be ultimately successful but that perhaps the greatest legacy of the MTT and e-books will be the added scaffolding afforded struggling readers through the interactive/enactive and audio encoding systems that allow for multi-sensory and dual-coding learning for struggling readers.

We, however, end with this caveat: The maxim that a picture is worth a thousand words fails to consider when the pictures are intertwined with the text to facilitate comprehension; however struggling readers cannot access the text: resulting in over reliance on the pictures to comprehend. Today, as more interactive graphic elements (IGEs) (e.g., simulations, image maps, animations, videos, audio files, etc.) are melded with text in earlier and earlier grade levels comprehension may be jeopardized rather than enhanced. This is particularly true when the technology does not compensate for the lack of teacher scaffolding (Slough & Rupley, 2010; Hui-Ling & Pedersen, 2011) and/or creates information overload (Chen, Pedersen, & Murphy, 2011).

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