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Applying Design to Learning: Cognitive Science Supports Visual Language Principles in the Design of Effective Reading Materials

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Abstract: *This experimental study examined whether formatting of textbook content influenced reader engagement, understanding or recall of topics. The 48-student population, ages 18-25, represented equal numbers of males| females with two levels of reader-ability, proficient and remedial. Four topics on nutrition were redesigned in grayscale to create three additional formats for each topic: original text with graphic mark-ups; chunked text; and visual language format, thereby producing 16 topic-format stimuli. After participants read four separate topics, each in a different format, they completed: a Personal Background Form; Multiple Choice Test; Prior Knowledge Form; written Survey; verbal responses to Open-ended Questions regarding formats read. This applied four conditions: Reading for Learning; Comprehension Test; Rank Survey; and Open-ended Questions, while incorporating three dependent variables - test scores, Likert scales and verbal responses. Quantitative and qualitative research methods found format statistically significant for influencing engagement, understanding and recall. Proficient and Remedial Male Readers' preferred visual-based formats yet tested highest on text with Graphic Mark-ups; Remedial Female Readers' preferred and tested highest on visual-based formats. Statistically significant data indicated all Reader Groups preferred visual-based formats for engagement, understanding and recall. While designing these formats, positive connectivity was found between cognitive science constructs and information design principles.*

Keywords: *Cognitive design, information design, reading, visual language*

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Introduction

Understanding the important role of learning in post-modern societies, opens the door to comprehend that students who learn less can suffer socially, economically, emotionally/psychologically and perhaps even physiologically. These affects, when shouldered by large numbers of individuals, can have a negative ripple effect throughout society that undermines the quality of life for all.

One of the most basic skills needed for learning is the ability to read. Statistics have shown that low-level reading ability inhibits learning, graduation from school, access to jobs, and is correlated with disorderly conduct (Bennett et al, p. 2443) increasing the probability of prison. According to Chall (1996, p. 165) "Reading is pervasive in its influence and its effects, and when people fail in reading; it becomes a personal tragedy as well as a societal problem" which only increases social inequities.

The need to address this topic is well documented. The following statistics, data and comments refer to the population in the USA. Stedman and Kaestle reported that "functional literacy tests suggest that 20 per cent of the adult population, or 30 million people, have serious difficulties with common reading tasks" (1987, p. 8). The National Center for Educational Statistics (NCES) reported on remedial education at degree-granting postsecondary institutions noting that in fall 2000, 11% of entering freshmen were "enrolled in one or more remedial reading, writing, or mathematics courses" (Parsad & Lewis 2003, p. iv). More recent studies have noted that many high school students cannot read above a fifth-grade level, and some cannot read much beyond a second-grade level (Archer, Gelason, & Vachon 2003, p. 89). In 2007, more than one-fourth of high school seniors scored below basic reading levels on the National Assessment of Educational Progress (NAEP).

In addition, a further reading gap exists within the mainstream of the educational system that includes a range of individuals who are not identified as special needs students or remedial readers, but whose difficulty with reading has not been sufficiently examined. For example, the 30-40 point difference on the NAEP in reading levels between "mainstream and minority [students] . . . has persisted with no significant change since 1970" (Labov 2003, p. 129). In addition, despite these serious concerns, "the field of reading," Labov noted, "has no present answer to the question of what to do about healthy children who do not learn to read" (p. 129). Without strong reading skills, other unclassified students (e.g., ADHD Students, Dyslexic Students, ESL Students, Lower SES Students, and Visual Learners) become marginalized from fully engaging in classroom topics (e.g., science, math, social studies). Neither do we know what to do with the growing population of healthy postsecondary "reluctant readers" and adult non-readers.

Design's role in redefining 'reading'

Perhaps one approach to understanding why some individuals have difficulty learning to read is to closely examine what is inferred when the word 'reading' is heard, voiced or viewed. In the genre of 'reading to learn', 'reading' infers the ability to interpret text into meaning from a 2D surface (e.g., paper, whiteboards, screens, billboards). Therefore, to clarify the topic being discussed, we need to acknowledge the importance of writing or saying 'reading text'. By inferring and thereby omitting the word 'text' after the word 'reading' implies that the only available form of reading to learn is through text-based formats. The definition of 'reading' in the 21st century needs to acknowledge all reading formats, not just text-based formats.

Research has shown that people have multiple ways of learning which leads one to logically postulate that perhaps multiple formats of reading are required for the learning process. This may be truer today than it was 50 years ago, before the age of technology, before the birth of our visual society. Publically acknowledging this presents challenges for schools and requires them to accept that the format itself has potential to hinder or assist readers in learning topic content. Current interventions focus on the readers and methodologies of instruction. Students who do not respond to standard linear text-based reading formats are segregated and isolated from mainstream text-based readers (Frey and Fisher 2004). Rarely has research focused on the format of the material itself. Instead, the focus includes teaching strategies such as decoding and whole language learning. Yet even with years of special training many students remain at low levels of reading comprehension.

To date, typical 2D reading formats have focused on the key elements of language (e.g., nouns, verbs, adjectives, sentence structure) with modest attention paid to the format of that content or the possible effect that design might have on students' overall ability to understand the content. Research across several disciplines and decades have repeatedly found a disparity between the needs of learners and the 2D materials used in classroom instruction. Information processing models and theories on working memory note that currently designed instructional materials which emphasize text over visual forms of information, present content in ways that create cognitive overload thereby lessening opportunities to learn (Sweller 1994; Bereiter & Scardamalia 1993). Research by cognitive psychologists on the topic of visual instructional methods, suggests the potential of visual-based materials increasing reading acquisition. These cognitive psychologists include: Holley and Dansereau (1984) who researched the effects of spatial elements on learning; Waddill, McDaniel and Einstein (1988) researched the inter-relationships of text and illustrations; Weidenmann (1989) studied the difference between effective and ineffective illustrations and; Winn (1997) examined the effective use of diagrams, charts and graphs in learning materials; Laura R. Novick et al., (2012) studied cognitive processing and comprehension based on line orientation in tree graphs (cladograms). In addition, information architects (Wurman 1994; Horn 1998; Lin 2007) have noted the potential format has for enhancing understanding and recall.

In order to meet this reading challenge, understanding two elements of learning procedure is critical: (1) teaching methodologies and (2) teaching materials. This study investigates the second element - teaching materials - specifically the formats that are used to present information in textbooks. This research was designed in order to determine whether the format of textbook content effects reader engagement, understanding or recall. The following questions formed the basis of this study:

- Are there significant effects on engagement, understanding, and/or recall when varied formats are applied to the design of textbook content?
- Does Reader Ability or Gender influence which format/s are more engaging, easier to understand, or facilitate recall?
- Does format effect Reader's test scores?

Research Methodology

In order to learn what formats best shape information content based on individual cognitive-learning needs, designing for effective user-centered transmission of

information may require restructuring topics and formats thus rethinking standard templates of information transfer. Knowledge from three fields was used to inform this 'rethinking' or development of format designs (stimuli) used in this research: Cognitive Science constructs (from both education and cognitive psychology), findings in the Neurosciences, and established principles from various disciplines within Graphic Design.

To investigate the above queries, the study incorporated a triangulation of research methods: participant Test performance, participant ranked Survey, and verbal responses to Open-ended Questions. Quantitative statistics were used to assess the Test and Survey results; qualitative methods were applied to open-ended Verbal Responses and observations. Therefore, the study included three dependent measures – Multiple Choice Test, Written Survey, and Open-ended Interview Questions.

Participants

Forty-eight postsecondary students, ages 18-25, representing an equal number of females and males from two groups of reader-ability, proficient and remedial, participated in this research. All Reader Groups include Proficient Female (PF) Readers, Proficient Male (PM) Readers, Remedial Female (RF) Readers, Remedial Male (RM) Readers, Proficient (P) Readers, Remedial (R) Readers, Female (F) Readers, and Male (M) Readers.

Twenty-four Proficient Readers were randomly selected from University of Wisconsin full-time student population who responded to one of the following: fliers, posters, signs, handouts, or word of mouth. They represented a variety of campus colleges and English was their primary language. The twenty-four Remedial Readers were students at a local technical college taking college preparatory remedial reading classes whose primary language was English, ages 18-25.

Research Design

The study was designed to examine how these populations read textbook content across four different design Formats. Once participants were identified using school ID's they were asked to read the Consent Form and sign if they wanted to participate in this study. Those who signed the Consent Form were given a Volunteer Packet coded by Set number and random ID Code.

VOLUNTEER PACKET

Section One | Four Stimuli. The study began with participants opening their Volunteer Packet to Section One which contained four stimuli covering the Topics of Energy, Vitamin D, Cravings and Food-borne Illness. Each participant viewed all four Topics only once with each Topic presented in a different Format. For example, some participants were shown the following combination: Energy Topic shown in original textbook copy (Text-only); Vitamin D Topic shown in original textbook copy with Graphic Mark-ups; Cravings Topic shown in traditional Chunked information style; and Food-borne Illness Topic shown in Visual Language design. The Test asked four questions about each stimulus totaling 16 questions incorporating four levels of difficulty. Twelve participants viewed the same Set of Topic-Format combinations. However, each participant viewed a randomly assigned Set in order to control Type I Error, thereby limiting the confounding variable of order-effect and strengthening internal validity of the study. When finished reading the stimuli, participants waited 10

seconds before turning to the next section. This allowed the brain to process the fourth stimulus before leaving Section One.

Section Two | Participant Background Form. This form served two purposes: (1) Questions were designed to identify past experiences that could have a potential influence on the outcome of the Multiple Choice Test, Survey and Open-ended verbal responses; and (2) filling in the Participant Background Form allowed for a span of time between reading the stimuli and taking the Multiple Choice Test. Information collected included: gender, age, year at postsecondary school, primary language, nutritional knowledge, science courses taken in high school and post-secondary school, source of nutrition knowledge, preferences when reading to learn, amount of visual art classes in high school, and intended postsecondary major. In addition to general information, these questions were included to provide insight into the participant's level of knowledge and interest in the Topic areas that might skew responses and contaminate the data.

Section Three | Multiple Choice Test. The 2-page test contained 16 questions incorporating four questions for each Topic. Each Topic contained a statement identifying a number, a word definition, an agent of change, and a general statement about the topic. Questions were developed for each of the Topics based on these four areas. The questions represented four levels of cognitive difficulty ranging from easy (Level 1) to most difficult (Level 4). Level 1 - Number Questions required recalling only one item from memory, the number itself (e.g., *"How many macronutrients contain energy?"*). Level 2 - Definitions were a well- defined word and its meaning which required a rote memorization skill that most postsecondary students are well-trained in (e.g., *"Nonfood items are called…?"*). Level 3 - General Statement Questions tend to be more obtuse and require more of an effort to recall (e.g., *"Cravings during pregnancy are mostly due to?"*). Level 4 - Cause and Effect Questions incorporate specific information with 2 actions to recall, a cause and an effect (e.g., *"Bacteria cause illness by..?"*). Presentation of Test questions had four randomized orders creating four Sets of Multiple Choice Tests for the 48 participants. Therefore, three participants in each of the four main Reader Groups (PF, PM, RF, RM) received tests from the same Topic/Format combination. However, each participant within that Set viewed the stimuli in a different sequence in order to limit the confounding variable of order effect.

Section Four | Prior Knowledge Form. Upon finishing the test, participants turned the page to complete a Prior Knowledge Form. They identified those Test questions that they knew the answers to prior to taking part in this study. The intent was to identify prior knowledge on any question in the Multiple Choice Test.

Section Five | Survey. Participants responded to seven Survey questions about the four Formats, using a 1-4 Likert scale. Copies of their Topic/Format combinations were placed in front of them on the table for use in responding to the questions. The majority of remedial readers preferred that the Survey questions be read to them. They then moved the four formats into rank order according to their responses to the question. Upon completing the Survey, participants were finished with the Packet.

Open-ended Questions. Participants were asked to verbally respond to seven Open-ended Questions based on the design Formats and Topics they read.

Query 1a) What made the first one [you chose] (Format A, B, C, or D) easiest for you to read?
1b) What made the last (Format chosen) the hardest to read?
Query 2a) What Format helped the most with finding specific information? Why?

2b) Which Format helped the least with finding specific information?
Were there any parts of the Format that hindered your efforts to find information?
Query 3a) Which Format was the easiest to understand? Why?
3b) Which Format was the most difficult to understand? Why?
Query 4a) Is there anything in the Formats that aided your understanding of the topic?
4b) Is there anything in the Formats that distracted you from understanding the topic?
Query 5a) Which Format or part(s) of Format aided recall during testing?
5b) Which Format did not assist recall during the test?
Query 6) Did Format influence your interest in the topic?
Query 7) If you could talk to textbook designers what would you suggest about textbook formats? How would you like to see textbooks designed?

Copies of their Topic/Format Set were once again placed in front of them for reference. The participant responded and then was encouraged to explain why s/he felt that way. Participants were audio-taped or responses were written by this researcher, depending on the preference of the participant. When finished with the Survey and Open-ended Verbal Responses the participant had completed the study.

Experimental stimuli

The stimuli content is from the textbook *Nutrition: ecology and behaviour* (Anderson, Wardlaw & Smith 2006). Four paragraphs were chosen representing four different Topics (Energy, Vitamin D, Cravings and Food-borne Illness). These Topics were chosen because they each contained a number to remember, a definition, an agent of change and its causal effect, and a general statement on the topic it was addressing. The formats are (see Table 1):

Table 1. Format names and descriptions.

Format A Text- only (See Figure 1)	**Format B** Graphic Mark-ups (See Figure 2)	**Format C** Chunked Text (See Figure 3)	**Format D** Visual Language (See Figure 4)
Original textbook format.	Adds graphic mark-ups to text (Italics, bold fonts, enlarged fonts, underlining, and highlights).	Reformatted content. Chunked information Apply Bullets, Tables, varied fonts, grids, tabbed columns. Some sentences.	Graphic fusion of words, images & symbols.
Text-based Formats		**Visual-based Formats**	

Passages from the book were chosen based on containing similar features in order to ensure topics were parallel and balanced in content. Features used to identify balanced content were: number of words, characters omitting spaces, characters including spaces, sentences, paragraphs, lines, numbers, locations mentioned, causal factors, dates/times used, and units to study for the Multiple Choice Testing condition.

Similarities that already existed among the topics selected are: a) they originated from the same textbook; b) were written to the same reading level; and c) covered approximately the same amount of visual space when in original text format. Both the Fogg and Smog Indexes indicate that passages within the book are written at the 18-19 year old reading level. Each Topic was redesigned in three different grayscale Formats containing the same information as the original paragraph using constructs from cognitive research and visual language principles.

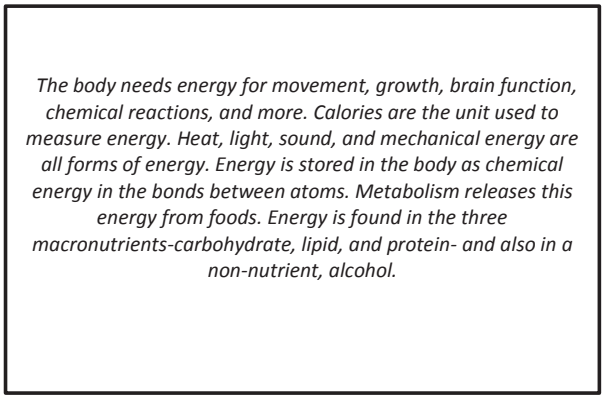

Figure 1. Energy topic in original Text- only | Format A.

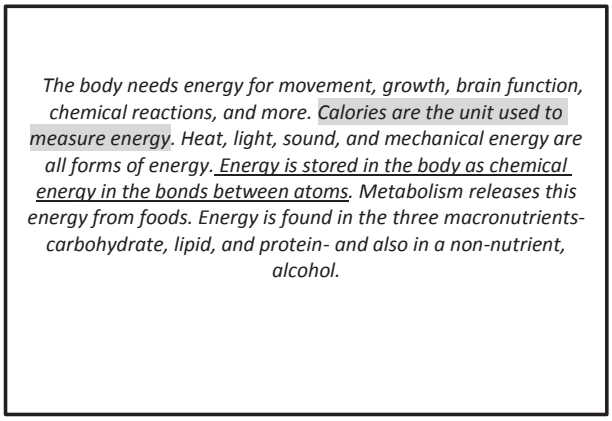

Figure 2. Energy topic in original text with Graphic Mark-ups| Format B.

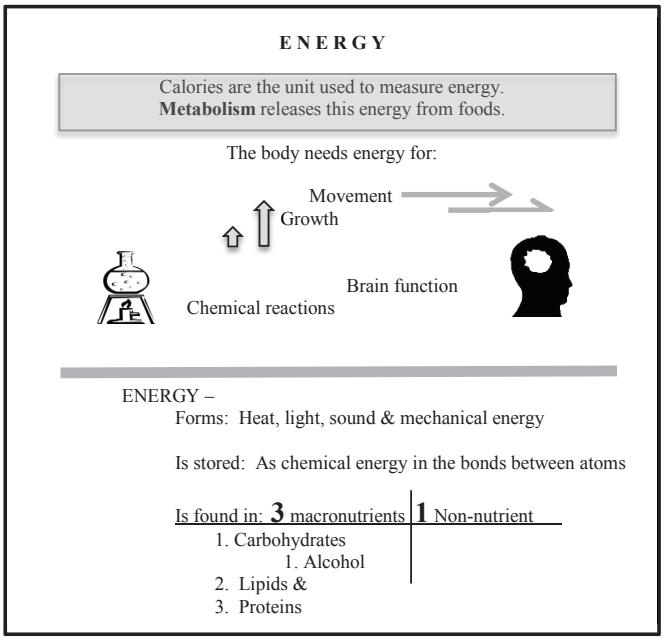

Figure 3. Energy topic in Chunked Format| C.

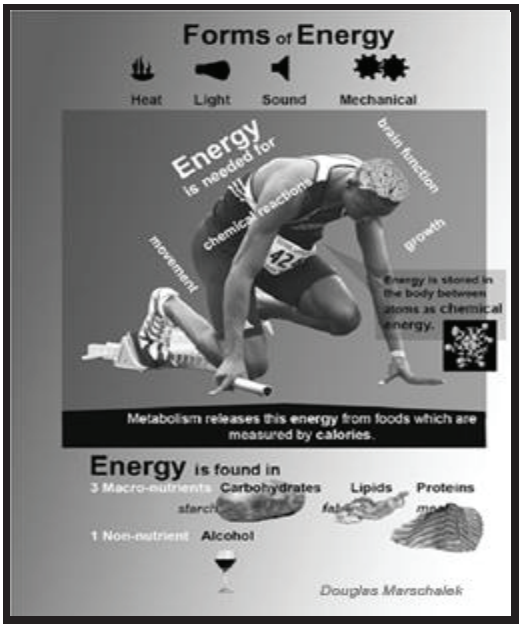

Figure 4. Energy topic in Visual Language | D. Source: Douglas G. Marschalek, Design Educator.

Table 2. Cognitive constructs with corresponding Visual Language Principles used to design Formats.

Cognitive Constructs	*Visual Language Principles*
Split Attention. Formats that force readers to visually seek, find and combine information requiring double processing interferes with learning core material (Sweller 1994).	Semantic Overlap uses specific visual language (VL) elements to "guide readers through the document and to cluster elements together" (Horn 1998, p. 186). This eliminates splitting the attention of readers.
Attentional Capacity is limited. Prolonging learner attention to identifying key elements and component processing of reading material can lead to poor reading habits (LaBerge & Samuels 1974).	Focusers are "Small, discrete visual elements used to organize smaller areas of the page…to attract readers attention…at a specific place, or to delineate a collection of objects or text (Horn, p. 185). This allows for more efficient learning during limited attention spans through guided episodes of designed focal areas.
Element Interactivity. Integrating various elements into instructional design that are not intrinsic to core content or when placed visually inconvenient can interfere with learning (Paas 1992).	Compositional Semantics focuses on using only pertinent words, images and symbols in visually tight construction units (Horn, p. 145). This helps eliminate extraneous or misplaced content, limiting element interactivity.
System Topology identifies components and labels them (Mayer & Gallini 1990).	Labeling integrates verbal and visual elements in order to distinguish terms parts and functions (Horn, p. 173).
Component Behavior identifies components and shows how they change, naming parts, steps and sequences (Mayer & Gallini 1990).	Transition Taxonomy. VL semantics use multiple taxonomies to identify transition (Horn, p. 153). These combined with labeling, identify component behavior.
Cognitive Overload occurs when short term memory can no longer process what it is seeing due to "disparate sources of information [being] physically integrated" (Sweller 1994, p. 204).	Information Design Principles organize designs to stay within memory limits (Horn, p. 237).
Schema Acquisition is a cognitive construct that states the brain organizes information according to meaning (Sweller 1994).	Semantic Fusion occurs when designers make "…meaning out of the tight integration of words, images and shapes…" (Horn, p. 97) through chunking and clustering information. This aids in building accurate schemas which increases the probability of understanding content.
Information Processing Models & Memory Systems are learning models that address and show that short term, working memory can process only limited amounts of information at one time (deKleer & Brown 1985).	Percept-Concept Integration. This principle includes and integrates percepts (objects shown as visual images) and concepts (mental ideas shown in text) into units easing comprehension, retention and retrieval (Horn, p. 95)
Theories of Expertise. Experts chunk information into meaningful units for ease of retrieval and to build new knowledge upon (Bereiter & Scardamalia 1993).	Chunked Information clusters words, images and shapes providing units of information based on perception principles and memory (Horn, p. 104 & 187).

Results

The variables of Topic, Set, Prior Knowledge, reading Preference, and Levels of question difficulty did not significantly influence test scores, therefore, it can be said that scores in this study are primarily a direct result of the reader's interaction with the Format. Based on these findings, further data analysis focused only on the Formats.

Data Analysis

Study design combined with selected queries determined the type of analyses for the research project. Identified queries indicated that both quantitative and qualitative analyses would be important for interpreting the data. Quantitative analysis was applied to data using software programs SPSS and Excel. Data was entered and analyzed for significant main effects and interactions. Post hoc tests analyzed significance between and within variables in pairwise comparisons and within three-way interactions of variables.

METHODS OF ANALYSIS

Data was collected from Multiple Choice Test scores and Survey responses. An analysis of variance (ANOVA) was run on all factors. The data from each of these factors was then analyzed separately using ANOVA's. These ANOVA looked at Between Summed Formats (Format A x B x C x D), and Between and Within Summed Reader Groups (Proficient and Remedial by Gender). Upon finding significance ($p \leq .05$), post hoc tests were applied that included Fisher's LSD and T-tests (F-tests) for statistically significant main effects and interactions. Spearman's rho test, designed to statistically analyze ranking data, was applied to Survey responses. Qualitative analysis was applied to data from the one-on-one interviews where participants verbally responded to Open-ended Questions. Analysis included descriptive research methods, identifying patterns, frequencies, averages, percentiles and relationship of responses compared to Multiple Choice answers and Survey responses. *All of the following data were found to be statistically significant* unless otherwise noted. Throughout this document when Reader Groups are listed and discussed, it is done so alphabetically and not by ability or gender.

MULTIPLE CHOICE TEST| Six variables were assessed using analysis of variance (ANOVA) in order to interpret the impact of Format design on test scores. The variables assessed were: Format design, Topic, Set, Level of Question Difficulty, Prior Knowledge of the question, and participants Preference of Reading Order for text and images. When participants had prior knowledge (PK) of certain questions, those responses were deleted from the data. With PK removed, test scores represented testing of 'new knowledge'. This helped level the playing field between proficient and remedial readers test scores. Formats for Gender were statistically significant at $p = .037$ (see Figure 5). This analysis reveals that Female Readers had higher test scores reading Visual Language Formats (D) while Male Readers scored higher on Text-only Formats (A) when reading new information.

Based on quantitative analysis of participants' test scores, there was no singular Format design that generated a universal increase of understanding or recall when reading material presented either known or new information.

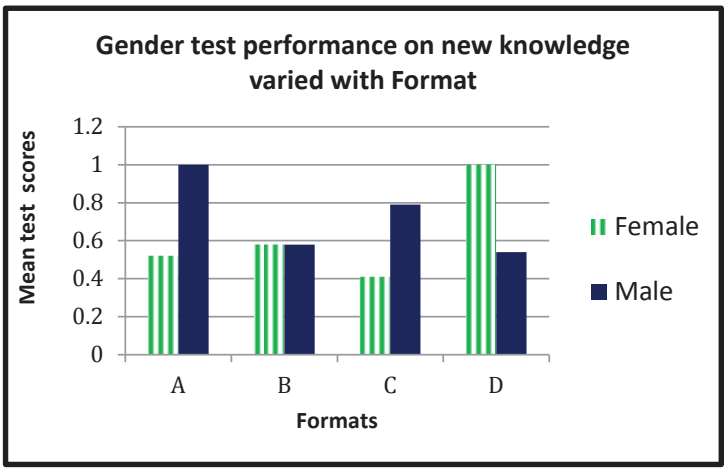

Figure 5. Female Readers scored significantly higher on Visual Language Formats (D) while Male Readers had higher test scores in Text-only Formats (A) when answering questions pertaining to new knowledge.

SURVEY DATA RESULTS | Participants responded to seven questions on the Survey form. Each question asked participants to rank Formats according to the question asked. The Survey tool used Likert scales for ranking responses using a four-point scale. (1 = lowest rank, 4 = highest rank.) Survey questions required participants to assess the Formats they had read in their Packets. Participants sorted their four Formats from:

1. Easiest to most difficult to read
2. Most to least informative
3. Most to least engaging
4. Most assisted to least assisted understanding
5. Most assisted to least assisted recall
6. Favorite to least favorite format for presenting information
7. Most to least favorite way they would like to see information in textbooks.

After the participant sorted their Formats in response to a question, the researcher recorded the ranked positions on the Survey form. Significant main effects for Formats were found for questions 1, 3, 4, 5, 6, and 7 ($p \leq .01$). Question 3 was significant on two levels 1) Format and 2) Format|Reader Ability|Gender. Significance was $p \leq .013$ for all main effects. The visual-based formats (Chunked and Visual Language) were found by both Reader Ability and Gender to be the easiest to read, most engaging, most helpful in understanding content, the easiest to recall, participants' favorite format, and the format they would like to see in textbooks (see Figure 6). In addition, Remedial Males ranked Visual language formats significantly more engaging than Proficient males (see Figure 7). Responses to Query 2 were not significant.

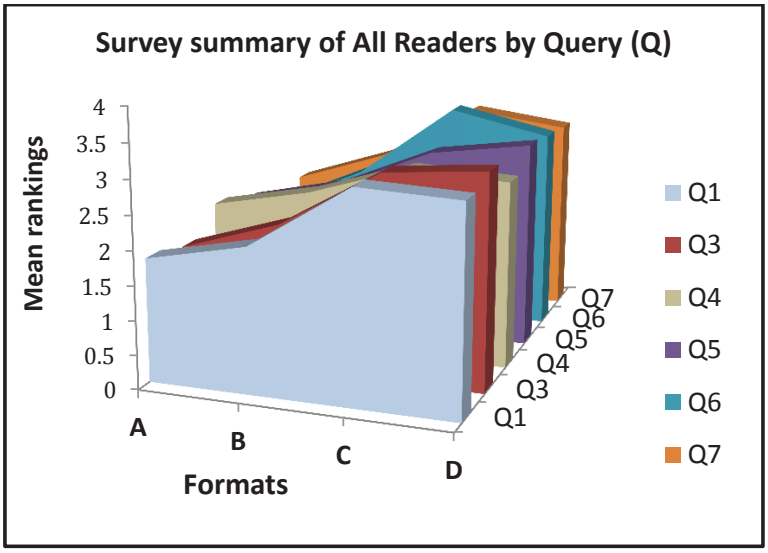

Figure 6. Visual-based formats - Chunked (C) and Visual Language (D) were found by All Readers to be the easiest to read [Q1], most helpful in understanding content [Q4], the easiest to recall [Q5], participants' favorite format[Q6], and the format they would like to see in textbooks[Q7]. Visual-based formats were also most engaging [Q2] for Female Readers and Remedial Male Readers but not Proficient Male Readers (see Figure 7).

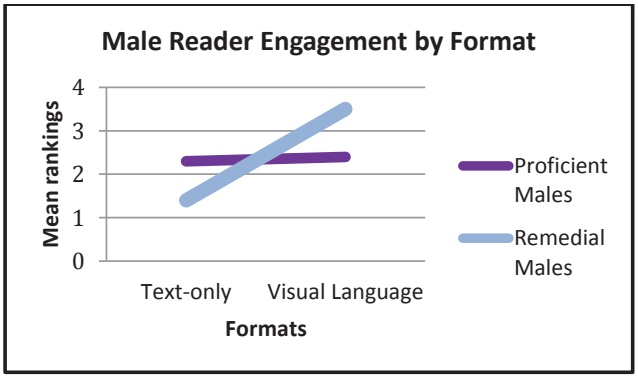

Figure 7. Remedial Male readers ranked format important to their level of engagement with content finding Visual Language formats significantly more engaging than Text-only formats. Proficient Male readers indicated that there was no singular format that was significant to their engagement.

OPEN-ENDED QUESTIONS. Analysis for this data used both inferential statistics and descriptive qualitative analysis pertaining to patterns, frequencies, averages, and relationships of responses. These questions were based on the Survey questions but addressed layout and design aspects of the formats, reader preference, readability, and clarity of content. Participants' answers were audio-recorded and transcribed. The purpose of including Open-ended Questions was to: 1) provide opportunity for participants to verbalize their thoughts; 2) discern participants' preference for, and

experiences with textbook content; and 3) aid in understanding participants previous responses to the Survey questions.

According to analysis, Ease of Reading, Understanding, and Recall were enhanced by visual-based formats|Chunked (C) and Visual Language (D) with $p \leq .001$ than by Text-only (A) formats across Reader Ability and Gender (see Figure 8).

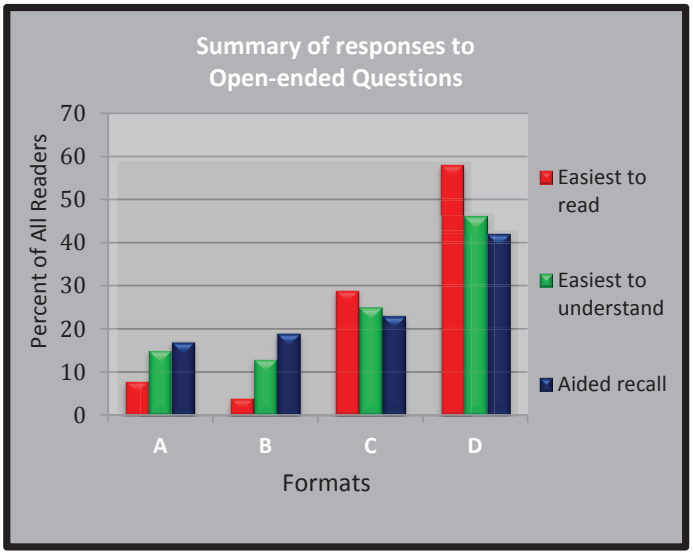

Figure 8. Ease of Reading, Understanding, and Recall were significantly enhanced by visual-based formats - Chunked (C) and Visual Language (D) than Text-only (A) formats across Reader Ability and Gender.

Based on these research findings, two significant issues emerged:

1) All four Reader Groups - Proficient Readers, Remedial Readers, Female and Male Readers – reported the best format for: engaging them in the topic; understanding the topic; and ease of recalling the information was visual-based formats.
2) All four Reader Groups agreed that the: least engaging format; most difficult to comprehend; and most difficult format to recall was a Text-only presentation of information.

Discussion

There is a growing body of evidence indicating that a close relationship exists between reading ability and topic comprehension, general grade-level abilities and school dropout rates. Currently, the bulk of reading materials are geared toward those students who learn best through reading text. The majority of reading materials in classrooms do not take into consideration many students who learn better through other reading styles. This study found that students across multiple learning styles and abilities are more engaged with, prefer to read, can understand and recall information easier with formats that use reformatted and cognitive-based visual language formats, than dominant text-based material. These findings coupled with aforementioned

theories and scientific observations of cognition point to the need for instructional content to be shaped by cognitive-based designs rather than traditional publication formats.

The data suggests that visual reading materials designed based on cognitive research could potentially engage more students in essential topics, assist in understanding and recall, encouraging positive learning results for a broad cross-section of students. Thus the format for presenting information could be as important to learning 'how to read' as current text-based intervention techniques. The need and importance for reading text-based material is important and whole-heartedly supported. However, text need not be the only format for presenting subjects such as science, technology, engineering, mathematics, or procedural knowledge. Text-training should not, and does not need to, infringe upon time needed to learn critical content. A broader range of formatted material is encouraged *in addition to text-based formats* in order to include a wider range of learners. Varied reading formats could provide more egalitarian ways of presenting information in a variety of learning environments (i.e., classrooms, training, on-line). In addition, different format designs may be necessary for new vs. prior known information.

On completion of this study, it became apparent that the Multiple Choice Test was biased toward text-based readers based on its traditional format and may have skewed the test results toward readers of text. In addition, there was the assumption that all participants would have similar cultural capital when it came to interpreting visual messages. Since the majority of such experience comes from the media (e.g., TV, computer games, video/movies, advertising, comics, graphic novels) and is readily available to participants in this study, assumptions were made that by some intuitive ability participants had acquired the skill of 'reading' visual language. This may be an inaccurate assumption. There were participants that did not automatically understand how to read the visual language format. They found it difficult to transition from reading text to reading a graphic form of information. A few readers noted being more comfortable obtaining information from text than from images and there were a couple Remedial readers who were not quite sure what they were supposed to do with visual language formats (e.g. what was the proper way to 'read' it). This lack of familiarity with visual reading may place individuals at an increasing disadvantage in this rapidly growing visual culture of the 21st century.

Certain questions arose during this study which merit consideration. How valid is the assumption that just because a participant likes a certain format, that they will be willing to spend more time with it and thereby increase probability of learning? Because a participant likes a format does not necessarily mean it's the best learning tool for them. What a participant 'likes' is part of the visceral or emotive response to their world, one that can gravitate toward comfort and security. Another concern was the high percentile responses by all Reader Groups to the visual-based formats. These unanticipated responses raise questions such as: Did participants want to please the researcher or do they really prefer visual-based formats? Did they answer according to what they thought was expected of them? Did they choose visual formats because of its novelty?

The fact that no singular Format generated a statistically significant dominance in comprehension or recall suggests that: 1] Both proficient and remedial post-secondary students have learned how to interpret text, to varying degrees, and 2] reading new, relatively unfamiliar visual-based formats generated similar test scores as text-based formats. This indicates that readers performed nearly as well, and sometimes

performed better on formats for which they had received modest to no training (visual-based formats) compared to the 12+ years of text training. This begs the question: If the same amount of time were spent on teaching with formats that are designed using cognitive science and visual language, would learning become more accessible to a wider range of students, resulting in a better educated population?

Conclusion

Findings in this study indicate a potential array of research that could be pursued, thus highlighting the need to replicate this research project in order to substantiate or refute its findings. Only with further research will definitive answers be determined as to the role of cognitive-based visual formats in the learning process.

The implications that format design could improve engagement, understanding and recall are pertinent to multiple fields. These findings, if substantiated by further research, could have a wide-ranging effect on Graphic Designers, Publishers, Businesses, Hospitals, Schools and other organizations.

GRAPHIC DESIGNERS

In order to design cognitive-based visual formats for learning, graphic designers would need to be trained in what constitutes cognitive-based information design (CID™). If CID™ formats offer a key to better understanding and recall of content presented, the demand for people trained in cognitive design methods could increase dramatically. In turn, this could create a new specialty path in the Graphic Design field.

EDUCATORS

Designing visual-based information based on cognitive constructs could provide educators valuable and effective learning tools. School leaders, be they teachers, administrators, or board members will need to be educated as to the benefits of CID™ formats. They will need to: a) be trained to recognize authentic CID™ formats in order to be wise consumers; b) learn how to create it for classroom and communication tasks; and c) learn compatible teaching methodologies in order to use them effectively.

STUDENTS

Starting with pre-school students and continuing through the educational systems, students could experience CID™ formats as an additional path to text-based reading in learning scholastic content. If a simple item such as format helps more students to understand content and remain mainstream students, it might also then have a role in improving school behavior, encouraging lower absenteeism and higher self-esteem by creating fewer marginalized students. Students who are Proficient Readers of text could use CID™ Formats to deepen their concepts of the topic being taught and/or use them as discussion and exploratory aids. Remedial Reading Students could have options to choose what type of format they learn from best. English Second Language (ESL) could use these visual-based formats to enhance vocabulary, grammar and engage in content discourse, which in turn aids in language acquisition and contextual understandings while building cultural capital.

PUBLISHERS

Could publishers see this as an opportunity to be the first source offering content designed based on scientific constructs thereby embracing the new science of reading? It would not require investment in new equipment, but investment in people trained to design for the cognitive process of learning.

ORGANIZATIONS

Any organization that needs to transmit information and perform training sessions could benefit from cognitive-based information design (CID™) formats – i.e., businesses, governments, hospitals, churches. These formats could have a positive effect on the rate of learning, interest in learning, engagement with and retention of topic information resulting in more effective training sessions. In addition, these formats have the potential to be affective across learning styles, across culture, across age groups.

These statements have been made based on statistical analysis of participants' performance (Test scores) and noted preferences (Survey and Open-ended Questions). However, it is important to bear in mind the small number of students (48) who participated in this study. Researching larger populations and iterations of this study could reveal further insights into the role formats have in the learning process.

References

Anderson, P., et al. 2006. *Nutrition: ecology and behavior*. New York: McGraw-Hill Companies.

Archer, A. L., et al. 2003. "Decoding and fluency: foundation skills for struggling older readers". *Learning disability quarterly* 26(2): 89-101.

Bennett, K.J., et al. 2003. "Does low reading achievement at school entry cause conduct problems?" *Social Science and Medicine* 56: 2443-2448.

Bereiter, C. and M. Scardamalia. 1993. *Surpassing ourselves: an inquiry into the nature and implications of expertise.* Chicago: Open Court Publishing Company.

Chall, J. S. 1996. *Stages of reading development*. Fort Worth, TX: Harcourt, Brace & Company.

Dehaene, Stanislas. (2009). *Reading in the brain: The new science of how we read.* New York: Penguin Books.

deKleer, J. and J.S. Brown. 1985. "A qualitative physics based on confluences". In *Qualitative reasoning about physical systems*, edited by D.G. Bobrow, 7-83. Cambridge, MA: MIT Press.

Frey, N., & D. Fisher. 2004. "Using graphic novels, anime, and the internet in an urban high school". *English Journal* 93 (3): 19–25.

Holley, C. D., & D.F. Dansereau. 1984. *Spatial learning strategies.* San Diego, CA: Academic Press.

Horn, Robert E. 1998. *Visual language: global communication for the 21st century.* Bainbridge, WA: MacroVU, Inc.

LaBerge, D. & S.J. Samuels. 1974. "Toward a theory of automatic information processing in reading". *Cognitive Psychology* 6: 293-323.

Labov, W. 2003. "When ordinary children fail to read". *Reading research quarterly* 38(One): 128- 131.

Lin, Tingyi. 2007. "Multifaceted Graphics for Learning: A Case Study on Explaining Projectile Motion in a University Physics Course". Unpublished doctoral dissertation, University of Wisconsin, Madison.

Mayer, R. E. and J.K. Gallini, J. K. 1990. "When is an illustration worth 10,000 words?" *Journal of Educational Psychology* 82 (4): 715 - 726.

Novick, Laura R. et al. 2012. "Reading Phylogenetic Trees: The Effects of Tree Orientation and Text Processing on Comprehension". *BioScience* Aug 2012, Vol. 62 Issue 8: p757-764.

Paas, F. 1992. "Training strategies for attaining transfer of problem solving skill in statistics: A cognitive-load approach". *Journal of Educational Psychology* 84: 429-434.

Parsad, B. et al. 2003. "Remedial education at degree-granting postsecondary institutions in Fall 2000: statistical analysis report" *I. o. E. S.* US Department of Education, National Center for Education Statistics: 95.

Stedman, L. and Carl F. Kaestle. 1987. "Literacy and reading performance in the United States, from 1880 to the present". *Reading research quarterly* 22(One): 8- 46.

Sweller, J. and C. Paul. 1994. "Why some material is difficult to Learn". *Cognition and Instruction* 12(3): 185-233.

Waddill, P. J. et al. 1988. "Illustrations as adjuncts to prose: a text-appropriate processing approach". *Journal of Educational Psychology* 80: 457-464.

Weidenmann, B. 1989. "When good pictures fail: an information-processing approach to the effects of illustrations". In *Knowing acquisition from text and pictures*, edited by H. Mandl and J. R. Levin, 157-171. Amsterdam: Elsevier.

Winn, B. 1987. "Charts, graphs, and diagrams in educational materials". In *The psychology of illustration,* edited by D. M. Willows and H. A. Houghton. Vol. 1: 152-198. New York: Springer-Verlag.

Wurman, Richard .S. 1994. *Information Architects.* New York: Watson-Guptill Publications Inc.