Students Learn More with Less Text that Covers the Same Core Topics

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Abstract—**For textbooks on technical topics, the typical amount of text used is more than what many college students will read. Some teachers observe, and students report, that students commonly skim such text. As such, a writing style that aggressively minimizes text while still teaching the core technical topic may improve student learning; if text is short enough, students may then read and study the text more carefully.**

The objective of this study was to compare the effect of text quantity on amount learned.

We created and compared content styles using a lesson that taught Google search techniques. The two main content styles were normal text and minimal text. The normal text style included 6-12 sentences followed by 1-3 examples. The minimal text style included 1-2 sentences followed by 1-3 examples.

We conducted a randomized control study with 168 participants enrolled in a college-level Introduction to Computing course for non-computing majors. Each participant was randomly assigned one lesson style. We provided a pre-lesson and post-lesson quiz, each with ten questions. Additionally, the participants completed background and follow-up surveys. The study was part of a course homework assignment, so self-selection bias was limited. The course is primarily taken by non-majors and covers the basics of Word, Excel, and HTML.

An improvement score is a participant's post-lesson minus pre-lesson quiz scores. The average improvement score for minimal text was 2.4 (6.5 − 4.1), which is higher (p-value < 0.01) than the average improvement score for normal text of 1.1 (5.1 − 4.0).

Thus, teaching the same topic using less text led to more learning. The conclusion is not that materials should be watered down, but rather that great attention should be paid to using minimal text while teaching the same core topics.

Keywords—digital learning; digital education; digital content; lesson assessment; text length, minimal text, college education, college textbooks, STEM.

I. INTRODUCTION

Completing textbook reading assignments improves student learning [4][10], and students are encouraged to complete the readings [3][9][13]; however, 94% of students spend less than two hours per reading assignment [1]. Text length may be a cause. Normal text lengths may use 6 − 12 sentences and 1 − 3 examples to cover a core concept, as shown in Fig. 2(a); whereas, minimal text lengths may use just 1 − 2 sentences and 1 − 3 examples, as shown in Fig. 2(b).

The objective of this study was to compare the effect of normal text and minimal text on the amount learned by students.

II. BACKGROUND

Cognitive load is the amount of mental effort a learner uses during a learning task. Cognitive load theory [8] defines three types of load: instrinsic, extraneous, and germane. Instrinsic load is the load added by the difficulty of the material. For example, adding two small integers has less instrinsic load than dividing two large integers. Extraneous load is the load added by the style of presentation. For example, a description of a square using a drawing has less extraneous load than with verbal descriptions. Germane load is the load added by developing an organized pattern of thought.

Research in instructional design has sought to reduce the learner's extraneous load and increase the germane load [11][12]. This paper focuses on the reduction of extraneous load by reducing the amount of text used to teach a subject.

Text length has been identified as an impactor of reader understanding [5]. Concise text was found to improve usability by 58% [7], where usability is defined by: time to complete a task, errors made during the task, amount remember by user after task, time to recall site's structure, and subjective satisfaction of the user. Longer text has been shown to negatively impact student understanding for secondary language learners [6]. Also, converting written text to spoken text has been shown to reduce extraneous load [2]. However, previous work has not simply measured how much text length impacts the amount a student learns. The problem is especially critical for STEM (science, technology, engineering, math) topics where a solid conceptual understanding of concepts is crucial for a student's continued success in an academic program. We have developed materials using an aggressively minimized-text approach, with ancedotal evidence that the minimal-text approach was well-liked by students and led to improved learning; this paper seeks to provided concrete evidence via a controlled study.

III. Participants

The participants were undergraduate students at the University of California at Riverside enrolled in a basic computing course during the 2013 Fall quarter. The course (CS 8 Introduction to Computing) introduces basic computing applications such as Microsoft Office and web applications, intended for non-computing and non-engineering majors and having no prerequisites. Traditionally, 98% percent of the students are non-computing and non-engineering majors.

307 students participated in the study, of which 164 were randomly assigned to a normal text group and 143 were randomly assigned to a minimal text group. Participants had one week to complete the assignment. Participants from the last three days spent an average of 2 minutes on the lesson, whereas students from the first four days spent an average of 7.5 minutes on the lesson. Thus, students from the last three days were excluded for clearly rushing through without trying and thus improperly skewing results. So, 85 participants from normal text and 83 from minimal text were included in the analysis.

The participants were blind to the conditions and specific purpose of the experiments. The participants were participating as part of their computing applications coursework. The experiments were approved by University of California at Riverside's IRB (Institutional Review Board).

IV. Design

Participants were given one week to complete the assignment by the instructor. Participants who completed the assignment in the last three days were excluded due to apparently rushing the assignment.

The two lesson styles were evaluated for quantity of learning and student engagement. A first measure was the number of correct answers on the pre-lesson assessment. A second measure was the number of correct answers on the post-lesson assessment. A third measure was the improvement score, which is the second measure minus the first measure. A fourth measure was the length of time spent on the lesson. Fifth through eleventh measures were the follow-up survey questions on how the lesson was used and how useful the lesson was perceived to be.

For each of the third through eleventh measures, we used a Student's T-test to determine whether the lesson styles were significantly different. The T-tests were computed with 2-tails and unequal variances parameters. We applied a Bonferroni correction to account for the multiple tests, so a p-value of $(0.05 / 9) = 0.006$ was needed for statistical significance.

V. Materials

The study was located on a single webpage and included 6 tabs. Only one tab could be viewed at a time, and participants could only progress forward between tabs. At the bottom of each tab was a button to proceed to the next tab. If the button was pressed for the first time but at least one of the input fields was not completed, then the page would generate a pop-up informing the participant that a field was incomplete. Otherwise, the current tab would disappear, and the next tab would appear.

The study page was titled: Digital Education Study. The page included that: "the purpose of this study is to evaluate different ways of presenting educational content." Also, the page included: "Your responses are completely anonymous." The participants were asked to "please refrain from leaving this webpage, using other devices, or asking others for assistance on the content."

In Tab 1, the participant was randomly assigned a unique

Fig. 1. The pre- and post-lesson assessments given to all participants included 10 multiple choice questions.

Num	Question	Your answers	Num	Question	Your answers
1	Songs that include the verse: Can't live without you.	○ Songs can't live without you ○ Songs "can't live without you" ○ Songs "can't" "live" "without" "you" ○ -Songs can't live without you	6	Resumes in the form of a word document.	○ resume filetype:doc ○ resume: filetype doc ○ resume word document ○ resume.doc
2	Light in the early morning or evening. Note: A popular movie named Twilight exists.	○ twilight ○ twilight not movie ○ twilight site:not movie ○ twilight -movie	7	Degrees at San Jose State University.	○ Degrees site:sjsu.edu ○ Degrees "sjsu.edu" ○ Degrees +sjsu.edu ○ Degrees ending:sjsu.edu
3	Job data provided by the government.	○ Job data site:.gov ○ Job data government ○ "Job data" government ○ Job data "government"	8	Sites that discuss George Bush but not George W. Bush.	○ "George Bush" "George -W. Bush" ○ "George -W. Bush" ○ "George Bush" -W ○ "George Bush" -"George W. Bush"
4	Research studies on smoking and cancer.	○ Smoking and cancer ○ Smoking and cancer (on scholar.google.com) ○ Smoking site:scholar ○ "smoking and cancer"	9	PowerPoint documents about the solar system.	○ solar system ○ solar system ppt ○ solar system filetype:ppt ○ solar system site:.ppt
5	Information on someone named Quincy Magoo.	○ Magoo, Quincy ○ Name:"Quincy Magoo" ○ "Quincy Magoo" ○ Quincy Magoo filetype:name	10	Research studies on regular, not electronic, cigarettes.	○ cigarettes ○ cigarettes (searched on scholar.google.com) ○ cigarettes -electronic (searched on scholar.google.com) ○ cigarettes not electronic scholar

Fig. 2. The first digital page of the (a) normal text lesson, and (b) minimal text lesson, representing about one-third of the entire lesson. The same examples were used in each style.

(a)

1 Google search tips

Searching the Internet for particular web pages, songs, movies, images, etc., is one of the most common tasks that a person performs on a computer today. Most people just use the basic standard search technique of typing in key words or even a full question, like: What low-cost foods are also healthy? While that technique often works, sometimes people get frustrated that when they just can't find what they are looking for, especially when what they are looking for is very specific. This frustration occurs not only during Internet searches, but also searching for a particular email too, which is very common these. However, there is good news: What many people don't realize is that there are a few search techniques that can really help narrow down those search results, hopefully leading to finding exactly what one is looking for.

Sometimes during a search, you are looking for a very specific combination of words. For example, you might be looking for a specific person who has a name like "Parviz Spaghetti". Consider the following search: Parviz Spaghetti. That search will turn up tens of thousands of pages, mostly about spaghetti, and people named Parviz, and much more. But really you are only interested in seeing pages about the specific person with the name "Parviz Spaghetti", and don't want to have to wade through thousands of pages.

Fortunately there is a solution. One of the simplest and most effective ways of finding something very specific during an Internet search is to use quotes. In a search, **quotes** around words causes the search to search for those words within the quotes, in the exact order that they appear within the quotes, without any other words in the middle. For example, "circle of knowledge" would only find sites with those three words in that order; a site with just "circle of your knowledge" would not match. Quotes are especially useful when searching for a specific phrase, like the famous statement from Albert Einstein about one's "circle of knowledge". Quotes are also very useful when searching for a person's name, using their first and last name.

For example, sites with *knowledge circle*, or *circle of your knowledge*, would NOT match with `Einstein "circle of knowledge"`.

Quotes are useful to find a specific combination of words. But sometimes the problem with search results is that search is returning pages that have nothing to do with the subject one is interested in, but instead just happens to use the same words as the search. For example, suppose you were searching for adventurous things to do in California, like perhaps mountain biking, whitewater rafting, cave exploring, etc. You might type the following keywords in your search: California adventures. But, the results would be entirely dominated by pages relating to the amusement park named: California Adventure, run by the Disney corporation What's needed is a way to *exclude* results that involve Disney, so the pages that really interest you appear.

(b)

1 Google search tips

Using *quotes*, as in "circle of knowledge", searches for exactly those words in that order. Quotes are especially useful for a specific phrase or a person's name.

| `Einstein "circle of knowledge"` | Sites with *knowledge circle*, or *circle of your knowledge*, would NOT match. |

Using a *minus* before a word, as in -Disney, excludes sites that have that word.

| `California adventures` | Results dominated by Disney's amusement park by that name. |
| `California adventures -Disney` | Results now mostly outdoor activity sites; no Disney info. |

Including *site:* in a search, as in site:.edu, restricts searches to domains with that ending.

`does soda cause obesity`	Yields news articles, opinion sites, university articles, etc.
`does soda cause obesity site:.edu`	Yields only pages from from Harvard, Stanford, Princeton, etc.
`does soda cause obesity site:harvard.edu`	Yields only pages from Harvard.

Including *filetype:* in a search, as in filetype:pdf, limits results to files of that type.

| `What is dry ice filetype:ppt` | Finds PowerPoint files discussing dry ice. |

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identifier that was associated with each activity and submitted answer by the participant. The unique identifier was stored in temporary browser cache. Tab 2 was a brief background survey asking in which school or college the student's current or intended major was, in what year in college the student was, and an agreeability statement: "I am very good at performing searches on Google." The agreeability statement had the following choices: Strongly agree, agree, slightly agree, slightly disagree, disagree, and strongly disagree.

Tab 3 was a pre-lesson assessment with 10 multiple choice questions, ordered the same for each participant, and shown in Fig. 1. Each question covered one or two concepts that were also covered in the lesson. At the top of the assessment, the participant was informed that these questions are to assess prior knowledge, so the participant was informed to "give each question your best and move on."

Tab 4 was a lesson on web searching with Google. The lesson was randomly assigned with equal chances to be either the minimal text or normal text style, shown in Fig. 2. Both styles covered the same concepts, including the same $1 - 3$ examples per concept. Minimal text had 211 words; normal text had 1,255 words. A timestamp was recorded when the lesson appeared.

Tab 5 was a post-lesson assessment with the same questions as the pre-lesson assessment. A timestamp was submitted when the post-lesson assessment appeared. Tab 6 was a follow-up survey with five agreeability statements about the lesson, two multiple choice questions assessing how the student interacted with the lesson, and an open-ended short answer question about the lesson style. The agreeability

statements were: "the lesson was sufficient to do well on the post-lesson quiz," "I was engaged with the lesson," "the lesson was the right length," "I liked the writing style," and "I am very good at performing searches on Google." The agreeability statements had the following choices: Strongly agree, agree, slightly agree, slightly disagree, disagree, and strongly disagree.

VI. Procedure

The course instructor assigned the study webpage as homework, in which the participants were given one week to complete the study webpage. The participants chose where and when to complete the study webpage. To maintain anonymity, after completing the study webpage, the participant filled a form to submit his/her student ID number—the student ID number was not associated with the randomly-assigned unique identifier. The instructor accessed the student ID number to award course points.

VII. Results and Discussion

An improvement score is a participant's post-lesson minus pre-lesson quiz scores. The average improvement score for minimal text was 2.4, which is significantly higher (p-value < 0.001) than the normal text improvement score of 1.1, as shown in TABLE I.

TABLE I. STUDENTS ASSIGNED MINIMAL TEXT IMPROVED SIGNIFICANTLY MORE THAN STUDENTS ASSIGNED NORMAL TEXT.

	Pre-lesson quiz	Post-lesson quiz	Improvement score
Minimal text	4.1	6.5	**2.4**
Normal text	4.0	5.1	**1.1**
		p-value	**< 0.001**

Additionally, participants rated agreeableness of statements on a scale of 0 (strongly disagree) to 6 (strongly agree). Participants rated "The lesson was the right length" for minimal text as 4.8, which is higher (p-value < 0.001) than the normal text score of 3.8, as shown in TABLE II. Also, participates rated "I liked the writing style" for minimal text as 4.3, which is higher (p-value = 0.03) than the normal text as 3.0.

TABLE II. STUDENTS ASSIGNED MINIMAL TEXT WERE SIGNIFICANTLY MORE SATISFIED WITH THE LESSON THAN STUDENTS ASSIGNED NORMAL TEXT.

	Normal text	Minimal text	p-value
Lesson was right length	3.8	4.8	< 0.001
Liked writing style	3.0	4.3	0.03

For the agreeability statement "The lesson was sufficient to do well on the post-lesson quiz", participants assigned minimal text rated 4.6 of 6 and normal text rated 4.5 of 6, which were not significantly different (p-value = 0.67). This suggests that both lessons covered the core topics sufficiently.

For the agreeability statement "I was engaged in the lesson", participants assigned minimal text rated 3.8 of 6 and normal text rated 3.3 of 6, which were almost significantly different (p-value = 0.09). The minimal text was more engaging, but not significantly so.

For the agreeability statement "I am very good at performing searches on Google" in the background survey, participants assigned minimal text rated 2.1 of 6 and normal text rated 2.1 of 6. However, in the follow-up survey with the same question, participants assigned minimal text rated 3.9 of 6 and normal text rated 4.4 of 6, which were almost significantly different (p-value = 0.01). The participant's belief in how much was learned was inverse to the amount actually learned. Perhaps the participants assigned the normal text believed they learned more because more text was presented; however, students actually learned more with the minimal text.

The question "How did you interact with the lesson?" had 5 options ranging from "I read every word in the paragraph text and examples" (rated as 5 of 5) to "I didn't really read the lesson" (rated of 1 of 5). Participants assigned minimal text rated 3.5 on average, which is almost significantly (p-value = 0.008) higher than normal text that rated 3.0.

The question "For reading assignments in your classes, how much of the assigned reading do you typically complete?" had 5 options from "100% of the reading" (rated as 5 of 5) to "0% of the reading" (rated as 0 of 5). Participants assigned minimal text rated 4.0 on average and normal text rated 3.9 (we would not expect a difference among the groups). So, the participants overall say they read about 75% of the assigned reading in their classes.

Participants spent more time with the minimal text (8.4 minutes) than the normal text (7.3 minutes); the difference was not significant (p-value = 0.83). Reading the normal text should have taken *longer* than reading the minimal text, so this indicates that participants may have skimmed over the normal text.

Minimal text naturally leads to a more structured presentation using items like tables or lists. To determine the impact of the tables used in the minimal text, we actually had a third group of students use a hybrid lesson using the normal text but with the examples in table form rather than text. Those students' improvement scores were about midway between the normal text and minimal text groups. We note however that the normal text in typical textbooks usually do not use tables in such an extensive manner due to resulting in unusual-looking content.

VIII. TECHNIQUES TO REDUCE TEXT

Creating minimal-text material requires careful attention to reduce text as much as possible while ensuring coverage of core topics, or as Antoine de Saint-Exupery wrote: "perfection is attained not when there is nothing more to add, but when there is nothing more to remove." Several general techniques were used for the minimal-text used in this study, including 1) concise and clear writing using simple declarative sentences, 2) avoiding or removing text that distracts readers from the core topic, and 3) matching the presentation format to the material presented. We highlight some examples of these techniques to illustrate.

One technique to write clear and concise text is to use simple declarative sentences, consisting of subject, verb, and object, as in "Quotes are especially useful for a specific phrase." This style specifically avoids using superfluous prepositional phrases, such as "when searching" in "Quotes are especially useful when searching for a specific phrase." Such prepositional phrases are only needed when the context is unclear; searching is clearly the context, and the prepositional phrase can be removed here without losing meaning. Additionally, a sentence should start with the real subject to clearly indicate the sentence's main point. Avoid starting sentence with pronouns, as in "It is", as the subject can be ambiguous, which may require some text elsewhere to clarify.

Another technique is to remove text that distracts readers from the core concepts, and focus on presenting core concepts first. While text motivating the need for a topic is important, such text should be kept to a minimum. One common method used to motivate topics is storytelling, often entailing setting up a scenario, defining actors, describing what the actors want to do, and finally introducing a problem they face, all before finally defining the core topic or concepts. Such motivational

examples may require 1-2 paragraphs and half a dozen sentences, as in the first two paragraphs of the normal-text style, shown in Fig. 2. The minimal-text approach instead presents the core topic first, then uses examples to provide the same motivation. With carefully chosen examples, the same motivation can often be conveyed without lengthy text that only serves to motivate. In some case, motivational examples may be needed. Motivational text should focus on providing the minimal text needed before introducing the core concept.

A third technique is identifying presentation formats that are best suited for the topics being presented. The minimal-text style used in Fig. 2(b) uses tables to present example searches with the left column presenting the search and the right column explaining. This presentation format avoids sentence text required to describe or present the example, as in starting a sentence with "For example" or "Consider the following search." Additionally, as the relation between the left-column example and right-column explanation is clear, the explanations start with "Yields" rather then "This example search yields"; further reducing text.

IX. FUTURE WORK AND LIMITATIONS

This study focused on one particular subject. An intrinsically more challenging subject may benefit more from minimal text, whereas an instrinsically less challenging topic may benefit less. Additionally, this study focused on how text quantity impacted learning. A list of writing rules and guidelines would be helpful for helping authors write clear and minimal text that help students learn more.

A future study might include each participant being shown multiple lessons, such that each lesson has a different lesson style. This may help better understand the students predisposition toward each lesson style.

Future work also includes assessing impacts of text length on multiple other topics, identifying and measuring rules for writing minimal text, and measuring additional learning formats for optimizing learning, such as clear writing, images, animations, learning questions, assessment questions, and interactive tools. Learning questions are another way of reading, wherein the student learns a concept by working through incrementally harder questions that start from a known concept. Assessment questions are designed to test a student's understanding.

One limitation of this work was that students were awarded course points for simply participating in the lesson and not awarded points for working through the lesson. Also, other than the participation of the lesson, the information in the lesson was not otherwise a part of the course. So, the incentive for a student to work through a lesson was missing.

X. CONCLUSION

The minimal text lesson had more than double the effectiveness than the normal text. The conclusion is not that materials should be watered down, but rather that great attention should be paid to using minimal text while teaching the same core topics.

REFERENCES

[1] Baier, K., C. Hendricks, K.W. Gorden, J.E. Hendricks, and L. Cochran. College students' textbook reading, or not. American Reading Forum Annual Yearbook. Vol. 31. 2011.

[2] Clark, R.C. and R.E. Mayer. E-learning and the science of instruction: Proven guidelines for consumers and designers of multimedia learning. John Wiley & Sons, 2011.

[3] Dartmouth Academic Skills Center. Active Reading: Comprehension and Rate. http://www.dartmouth.edu/~acskills/success/reading.html, visited April 2015.

[4] Gurung, R.A.R., and R.C. Martin. Predicting Textbook Reading The Textbook Assessment and Usage Scale. Teaching of Psychology 38.1: 22-28, 2011.

[5] Hidi, S. and V. Anderson. Producing written summaries: Task demands, cognitive operations, and implications for instruction. Review of Educational Research, 56, 473-493, 1986.

[6] Leow, R.P. The Effects of Input Enhancement and Text Length on Adult L2 Readers' Comprehension and Intake in Second Language Acquisition. Applied Language Learning 8.2: 151-82, 1997.

[7] Nielson, J. How Users Read on the Web. http://www.nngroup.com/articles/how-users-read-on-the-web/, visited April 2015.

[8] Paas, F., A. Renkl, and J. Sweller. Cognitive load theory and instructional design: Recent developments. Educational psychologist 38.1: 1-4, 2003.

[9] Pace University Center for Academic Excellence. Read Your Textbook. http://www.pace.edu/center-academic-excellence/tutoring-center/new-york-city-campus-2/musts-successful-study/read-your-textbook, visited April 2015.

[10] Ryan, T.E. Motivating novice students to read their textbooks. Journal of Instructional psychology 33.2: 135, 2006.

[11] Sweller, J. Cognitive load during problem solving: Effects on learning. Cognitive science 12.2 (1988): 257-285.

[12] Sweller, J., J.J.G. Van Merrienboer, and F.G.W.C. Paas. Cognitive architecture and instructional design. Educational psychology review 10.3: 251-296, 1998.

[13] University of Chicago Student Counceling Serice. How to Pre-read a Textbook Chapter. https://counseling.uchicago.edu/page/how-pre-read-textbook-chapter, visited April 2015.