A Comparison of Readability in Science-Based Texts: Implications for Elementary Teachers

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Abstract

Science curriculum standards were mapped onto various texts (literacy readers, trade books, online articles). Statistical analyses highlighted the inconsistencies among readability formulae for Grades 2–6 levels of the standards. There was a lack of correlation among the readability measures, and also when comparing different text sources. Online texts were the most disparate with respect to text difficulty. These findings suggest implications for elementary teachers to support students who learn through reading online, science-based resources. As 21st-century learning through multi-modal literacies evolves,

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the readability of online, content-based text should be evaluated to ensure accessibility to all readers.

Keywords: readability formulae, science-based texts, text difficulty, literacy, elementary education

Résumé

Des normes s'appliquant aux cours de science ont été intégrées dans divers textes (manuels de littératie, livres grand public, articles en ligne). Des analyses statistiques ont mis en relief les disparités entre les formules de lisibilité pour les élèves de la 2e à la 6e année. Il y avait un manque de corrélation entre les mesures de lisibilité, notamment lors de la comparaison entre des textes provenant de diverses sources. Les textes en ligne étaient les plus disparates quant au niveau de difficulté. Ces résultats semblent indiquer que les enseignants du primaire devraient offrir un soutien aux élèves qui apprennent en lisant des articles scientifiques en ligne. À mesure qu'évolue l'apprentissage à travers des littératies multimodales évolue au cours de ce siècle, la lisibilité du contenu en ligne devait être évaluée afin de garantir son accessibilité à tous les lecteurs.

Mots-clés : formules de lisibilité, textes scientifiques, difficulté du texte, littératie, enseignement au primaire

Introduction

Content area literacy is reading and writing in order to learn more about a domain or discipline (Moss, 2005). Instructionally, teachers access an assortment of text types and genres to connect content learning with literacy and technology skills. The outcome is enhanced learning and the ability to read, write, and discuss in authentic ways. This is especially integral to science learning and scientific literacy (Yore, Hand, & Florence, 2004). Comprehending, interpreting, analyzing, and discussing science are all functions of being scientifically literate (Norris & Phillips, 2003).

The intersection between reading and learning in science offers important considerations for educators to note when providing texts to assist elementary students in reading to learn science. Background knowledge and vocabulary are key components in a literacy-rich science curriculum, and are also important in providing the means to improve student understanding and achievement in science (Gallagher, Fazio, & Gunning, 2012; Gallagher, Fazio, & Ciampa, 2013; Fazio & Gallagher, 2014; Fisher, Grant, & Frey, 2009). This study examined the juncture between the accessibility of text and students' science knowledge. Accessibility of text is influenced by how readable the text is. With reference to readability, vocabulary repertoire contributes to reading fluency (Graves, 2006) and vocabulary knowledge influences text comprehension (Bravo & Cervetti, 2008). It is important to note that the instructional supports provided by the teacher are helpful for students accessing text.

Contemporary students have unprecedented access to texts they can use to read to learn in science. The term "text" refers to a range of print words, images, video, or sound, used to communicate and express (Semali, 2001). Texts take on different forms. Literacy or basal readers are grade-levelled sets of short passages compiled into one resource; some passages are précises of original works (Pilonieta, 2010). In Canada, literacy or basal readers are written in an attempt to correlate with learning outcomes from various curriculum or standards policy documents (Bainbridge & Heydon, 2013). Trade books are published, commercially sold books that combine printed words and pictures into a paper-bound text (Bintz, Wright, & Sheffer, 2010). Trade books are narrative or informational in nature, and can address a wide range of reading levels. Existing research documents the efficacy of using trade books to teach science concepts and enhance science vocabulary (e.g., Brassell, 2006; Ford, 2004; Holliday, 2004; Plummer & Kuhlman, 2008;

Saul & Dieckman, 2005). For the purposes of this research, online articles are defined as those texts that are accessed through the internet on websites designed for elementary students' education purposes. These digital texts and images include open-access sites and other online versions of magazines (Hiebert, 2013). The impact of such online reading in various content areas is a burgeoning field of research (Leu et al., 2007). The online articles accessed for analysis in this study were selected based on the topical content of the article (e.g., "Growth and Changes in Plants") and not by readability, text difficulty, or grade level.

It is important to note that the balance of literary qualities and science content in different texts (e.g., literacy readers, trade books, online articles) is delicate. This is a particular concern since both the International Literacy Association and the National Council of Teachers of English are critical of the use of readability formulae. Why? Readability formulae are inexact and improperly applied. Given the accessibility and extensive use of literacy readers, trade books, and online articles in the elementary classroom, close examination of readability in these sources of science-based text is warranted. Accordingly, the purpose of this study is to raise awareness of the discrepancies among common readability measures given the variety of text sources that elementary classroom teachers are accessing for use in science instruction. This research was framed by the following research questions:

1. How do text readability measures compare when mapped onto grade-specific science curriculum standards?
2. What are the differences among readability measures and text sources (e.g., literacy readers, trade books, online articles)?

Conceptual Perspectives

The *Common Core State Standards* (CCSS) (National Governors Association Center for Best Practices, Council of Chief State School Officers, 2010) notes that students need to read complex texts that contain novel language, new knowledge, and innovative modes of thought—these are earmarks of science-based text. Students now have clear expectations to read, talk, and write about informational text. The CCSS Model of Text Complexity (National Governors Association Center for Best Practices, Council of Chief State School

Officers, 2010) suggests that teachers need to consider not only readability but also text qualities such as vocabulary and students' prior knowledge and experience. Furthermore, the *Next Generation Science Standards* (NGSS, 2013) suggests that students should obtain, evaluate, and communicate scientific knowledge by reading, interpreting, and producing texts. It is clear that the standards in language and science intersect and point to a distinct direction for instruction: provide students with opportunities for learning about science in authentic and stimulating ways (National Research Council, 2011, 2014). Taken together, teachers have a dual challenge: to select appropriate informational texts that motivate students to read to learn and match grade-level content standards (Liang, Watkins, & Day, 2013).

Traditionally, primary and middle-school students have not had extensive exposure to a range of informational text (Lapp, Grant, Moss, & Johnson, 2013), and this exposure is essential for students engaging with content areas such as science. The informational genre includes persuasive, procedural, and expository text—all are instrumental in science inquiry and discourse. Yet science-based texts can be challenging for students to comprehend as they include compressed factual information and complex concepts that demand access to background knowledge (Johnson & Zabrucky, 2011). Moreover, readability can vary within an informational text passage depending on the format, text structures, and reader prior knowledge (Liang et al., 2013) and this makes it difficult to determine text gradients (Pitcher & Fang, 2007). Content-based text in science is also rich in description, but technical and dense in vocabulary, due, in part, to the Latin and Greek roots found in science vocabulary (Rasinski, Padak, Newton, Newton, & Bromley, 2008). Given that science vocabulary inflates readability (Pearson, Hiebert, & Kamil, 2007), elementary students may find it challenging to learn scientific concepts by reading content-based text in science.

Readability indices attempt to quantify the reading grade level at which a typical student can read a text. Over the past eight decades, over 200 readability indices have been proposed and utilized (DuBay, 2004). Some indices such as the Spache (1953) and Dale-Chall (Chall & Dale, 1995) refer to word frequency lists and factor vocabulary familiarity into readability calculations. Other readability indices such as the Gunning Fog (1952) are sensitive to the complexity of vocabulary in a given text. Others that are widely utilized by publishers (Chavkin, 1997; Pitcher & Fang, 2007) such as the Fry Readability (Fry, 1977) and Flesch-Kincaid (Flesch, 1948) use factors such as the number of sentences and the syllable count of the words in the passage. Finally, the Lexile Framework (MetaMetrics, 2015) uses sentence length and word frequency. It is commonly held that readability measures are a controversial estimate of text difficulty when compared to students' oral reading fluency (Begeny & Greene, 2014). Recent investigations into the reliability of readability indices has uncovered the lack of correlation among them and with teachers' qualitative readability estimates (Ardoin, Suldo, Witt, Aldrich, & McDonald, 2010; Heydari, 2012). In particular, readability measures may be ignorant of readers' interests, prior knowledge and conceptual understanding (Pitcher & Fang, 2007). Yet the irony lies in the reality that the aforementioned readability calculations are still readily used and referenced by publishers, teachers, and librarians.

Herein lies the conundrum that many teachers face when integrating content-based text: offering students varied text types and levels that appeal to their background knowledge, inquiries, and experiences. This is especially the case in science content instruction where teachers need to consider the range of genres and readability as a function of students' intrinsic motivation to read to learn about a topic (Handsfield, Karraker, MacPhee, & Wedwick, 2013). Teachers need to access and evaluate both print-based and multimodal texts and scaffold their students' reading of complex science-based information, while keeping in mind the reality that there are inconsistencies in text difficulty (Begeny & Greene, 2014). With such disparate variables in readability measures and the challenges that teachers incur in gauging readability, it is important to ask how the indices might compare and whether they are valid measures of various text sources for content area reading.

Methods and Data Sources

Science-based passages that aligned with grade-specific curriculum topics for Grades 2–6 (Ministry of Education Ontario, 2007) were sampled from literacy readers (*Nelson Literacy*, 2008), trade books (see sample in Appendix A), and online articles (see sample in Appendix B). Nine readability indices (see Appendix C) were calculated on a total of 848 passages. Lexile scores were obtained from the MetaMetrics (2015) database and were converted into grade-equivalent scores. These 10 readability indices were chosen based on their identification as commonly cited in reading research (Begeny & Greene, 2014).

For the grade-specific passages from each of the three sources of text—(1) literacy readers n = 146 passages (*Nelson Literacy*, 2008); (2) trade books n = 346 passages; and (3) online articles n = 356 passages—descriptive statistics were calculated (SPSS, 2012) using the readability indices. The results of the readability indices were correlated using a *Pearson's r product-moment correlation coefficient* (Isaac & Michael, 1997). Finally, the readability indices were compared within these texts sources for specific genres (e.g., reports, narratives, explanations).

Results

The following three subsections present the results of the analyses for the readability indices for each of the text sources, correlations between the readability indices, and genre-specific comparisons.

Readability Indices Compared within Text Sources

The descriptive statistics (e.g., means, standard deviation) in Tables 1, 2, and 3 that follow provide evidence of the disparity in the grade-specific passages and the lack of consistency among the formulae—with the exception of the Lexile formula.

Table 1. Descriptive statistics for means of readability formulae per grade (commercial literacy readers)

Formulae	Grade 2 (*M* ± *SD*)	Grade 3 (*M* ± *SD*)	Grade 4 (*M* ± *SD*)	Grade 5 (*M* ± *SD*)	Grade 6 (*M* ± *SD*)
Gunning Fog	5.0 ± 1.8	5.5 ± 1.6	7.1 ± 1.8	8.0 ± 2.3	9.4 ± 2.0
Flesch-Kincaid	3.5 ± 1.3	3.8 ± 1.3	5.4 ± 1.4	6.7 ± 2.0	7.6 ± 1.7
Fry	3.9 ± 2.1	4.5 ± 1.7	6.2 ± 1.9	7.8 ± 2.8	8.8 ± 2.5
Spache	2.8 ± 0.4	3.1 ± 0.5	NA	NA	NA
Dale-Chall	NA	NA	5.9 ± 1.3	6.4 ± 1.5	7.3 ± 0.9
Coleman-Liau	4.2 ± 1.9	5.6 ± 2.0	7.5 ± 1.5	8.2 ± 2.3	9.1 ± 2.2
ARI	1.6 ± 1.5	3.0 ± 1.8	4.7 ± 1.4	5.4 ± 2.0	7.0 ± 2.2
SMOG	6.1 ± 1.6	6.8 ± 1.4	7.9 ± 1.2	8.3 ± 2.1	9.9 ± 1.5
Lexile	2.5 ± 0.6	3.2 ± 1.0	4.7 ± 1.4	5.3 ± 1.7	6.3 ± 2.1

Table 2. Descriptive statistics for means of readability formulae per grade (trade books)

Formulae	Grade 2 ($M \pm SD$)	Grade 3 ($M \pm SD$)	Grade 4 ($M \pm SD$)	Grade 5 ($M \pm SD$)	Grade 6 ($M \pm SD$)
Gunning Fog	5.3 ± 1.5	5.4 ± 1.6	7.6 ± 2.2	7.1 ± 2.0	8.3 ± 2.1
Flesch-Kincaid	4.0 ± 1.1	3.8 ± 1.3	5.6 ± 1.8	6.0 ± 1.6	6.7 ± 2.1
Fry	3.4 ± 1.1	3.4 ± 0.9	5.6 ± 1.8	5.8 ± 2.0	6.8 ± 1.6
Spache	3.1 ± 0.4	3.3 ± 0.6	NA	NA	NA
Dale-Chall	NA	NA	6.4 ± 1.1	6.6 ± 1.1	6.8 ± 1.0
Coleman-Liau	5.8 ± 1.8	5.8 ± 1.9	7.6 ± 2.1	7.1 ± 1.9	8.1 ± 2.2
ARI	3.0 ± 1.5	3.2 ± 1.5	4.6 ± 1.9	4.5 ± 1.9	5.9 ± 2.3
SMOG	6.6 ± 1.3	6.6 ± 1.2	8.4 ± 1.6	8.2 ± 1.5	9.0 ± 1.7
Lexile	3.2 ± 0.8	3.2 ± 1.2	3.9 ± 1.3	4.2 ± 1.5	5.3 ± 2.1

Table 3. Descriptive statistics for means of readability formulae per grade (online articles)

Formulae	Grade 2 ($M \pm SD$)	Grade 3 ($M \pm SD$)	Grade 4 ($M \pm SD$)	Grade 5 ($M \pm SD$)	Grade 6 ($M \pm SD$)
Gunning Fog	6.5 ± 2.1	9.1 ± 3.8	7.7 ± 3.3	7.7 ± 3.5	7.4 ± 3.1
Flesch-Kincaid	5.0 ± 1.9	7.5 ± 3.6	6.2 ± 3.1	6.7 ± 3.3	5.8 ± 2.9
Fry	4.8 ± 1.9	7.2 ± 3.2	5.5 ± 2.5	6.2 ± 2.4	5.8 ± 2.8
Spache	3.8 ± 0.8	4.9 ± 1.4	NA	NA	NA
Dale-Chall	NA	NA	6.9 ± 2.6	7.1 ± 1.3	7.0 ± 1.1
Coleman-Liau	6.7 ± 2.0	9.1 ± 3.3	7.7 ± 3.1	8.1 ± 2.4	7.6 ± 2.5
ARI	4.1 ± 2.4	7.3 ± 4.0	5.5 ± 3.5	5.8 ± 3.8	5.1 ± 3.3
SMOG	7.7 ± 1.5	9.6 ± 3.1	8.5 ± 2.4	8.6 ± 2.4	8.4 ± 2.4
Lexile	3.9 ± 1.6	6.3 ± 2.9	4.8 ± 2.4	4.5 ± 2.5	4.3 ± 2.4

Correlations of Readability Indices within Text Sources

The results of the *Pearson's r product-moment correlation coefficient* are presented in Tables 4, 5, and 6. Given the deliberate and controlled readability of the commercial literacy readers, it is not surprising that all of the formulae correlated. However, for the trade books there were 26 out of a possible 35 correlations, and for the online articles there were only 17 out of a possible 35 correlations.

Table 4. Pearson product-moment correlation coefficient r for all grade levels and passages (commercial literacy readers)

Formulae	Flesch-Kincaid	Fry	Spache	Dale-Chall	Coleman-Liau	ARI	SMOG	Lexile
Gunning Fog	.92**	.89**	.56**	.65**	.86**	.84**	.87**	.91**
Flesch-Kincaid		.95**	.64**	.70**	.89**	.88**	.86**	.98**
Fry			.63**	.66**	.88**	.82**	.823**	.98**
Spache				.45**	.62**	.53**	.44**	.61**
Dale Chall					.62**	.66**	.67**	.69**
Coleman-Liau						.91**	.78**	.88**
ARI							.86**	.83**
SMOG								.85**
Lexile	.37**	.33**	.36**	.24**	.41**	.43**	.30**	.07

Note. ** = $p \leq .01$.

Table 5. Pearson product-moment correlation coefficient r for all grade levels and passages (trade books)

Formulae	Flesch-Kincaid	Fry	Spache	Dale-Chall	Coleman-Liau	ARI	SMOG	Lexile
Gunning Fog	.87**	.68**	.39**	-.05	.71**	-.22**	.93**	.87**
Flesch-Kincaid		.75**	.46**	-.03	.83**	-.22**	.88**	.93**
Fry			.34**	.02	.62**	-.30**	.70**	.76**
Spache				-.06	.44**	-.51	.25**	.36**
Dale Chall					-.03	.25**	-.06	-.06
Coleman-Liau						-.16**	.77**	.83**
ARI							-.23**	-.20**
SMOG								.82**
Lexile	-.22**	-.30**	-.05	.08	-.20**	.72**	-.23**	-.20**

Note. ** = $p \leq .01$.

Table 6. Pearson product-moment correlation coefficient r for all grade levels and passages (online articles)

Formulae	Flesch-Kincaid	Fry	Spache	Dale-Chall	Coleman-Liau	ARI	SMOG	Lexile
Gunning Fog	-.03	-.03	-.01	.13	-.03	-.04	-.03	-.06
Flesch-Kincaid		.64**	.92**	-.11	.89**	.97**	.95**	.95**
Fry			.45**	0.17	.57**	.62**	.61**	.62**
Spache				-.13	.83**	.93**	.88**	.89**
Dale Chall					-.07	-.09	-.08	-.09
Coleman-Liau						.91**	.88**	.92**
ARI							.92**	.92**
SMOG Lexile	-.03	.12*	-.00	.18*	.00	-.04	-.06	.94** -.03

Note. ** = $p \leq .01$.

Readability Indices Compared within Text Sources for Specific Genres

As a way of illuminating text differences, descriptive statistics were also calculated for specific genres of text (e.g., reports, narratives, explanations) from each of the above text sources. The five readability measures in Tables 7, 8, and 9 were chosen because together they are applicable for text at all grade levels (i.e., Spache is applicable up to Grade 3; Dale Chall is applicable after Grade 3) and based on pervasive use (Chavkin, 1997; Pitcher & Fang, 2007). For comparative purposes, three genres have been chosen at each grade level. The number of passages for each genre varies due to author/publisher distribution for each grade level. Readers are reminded that this is only a sample cross-section of the findings.

Table 7. Means of genre-specific readability calculations by grade level (commercial literacy readers)

Publisher /Author grade	Genre	Number of passages analyzed	Gunning Fog	Flesch-Kincaid	Fry	Automated Reading Index	Lexile
			(*M* ± *SD*)	(*M* ± *SD*)	(*M* ± *SD*)	(*M* ± *SD*)	(*M* ± *SD*)
2	Narrative	2	3.8±0.5	3.1±0.5	2.0±0.7	0.7±1.3	1.3 ± 0.4
2	Report	8	6.5±2.4	3.9±2.1	4.7±3.2	2.6±1.8	3.0 ± 0.8
2	Explanation	11	4.7±1.7	3.8±0.9	4.1±1.8	2.0±1.3	2.7 ± 0.6
3	Narrative	4	4.3±0.7	2.6±0.7	2.7±1.1	1.2±1.2	2.4 ± 0.9
3	Report	7	7.0±1.5	5.0±1.2	5.9±1.5	4.4±1.6	3.6 ± 1.2
3	Explanation	7	5.3±1.4	3.4±1.1	4.1±1.4	2.8±1.7	3.0 ± 0.7
4	Narrative	1	6.1±0.0	3.4±0.0	3.5±0.0	2.4±0.0	2.7 ± 0.0
4	Report	13	6.9±1.8	5.4±1.3	6.2±1.8	4.5±1.1	4.6 ±1.4
4	Explanation	6	7.4±1.6	5.5±1.7	6.0±1.9	4.8±1.2	5.6 ± 0.9
5	Narrative	1	6.2±0.0	4.8±0.0	5.5±0.0	3.9±0.0	4.3 ± 0.0
5	Report	11	9.0±1.8	7.6±1.6	8.9±2.5	6.4±1.6	6.4 ± 1.9
5	Explanation	16	6.9±2.0	5.6±1.6	6.3±1.9	4.7±1.8	4.7 ± 1.3
6	Narrative	0	-	-	-	-	-
6	Report	7	9.3±2.1	7.3±1.7	8.9±2.7	6.6±2.0	6.1 ± 1.7
6	Explanation	12	9.3±2.6	7.8±2.2	8.7±3.9	7.3±2.8	6.9 ± 2.4

Table 8. Means of genre-specific readability calculations by grade level (trade books)

Publisher /Author grade	Genre	Number of passages analyzed	Gunning Fog	Flesch-Kincaid	Fry	Automated Reading Index	Lexile
			(*M* ± *SD*)	(*M* ± *SD*)	(*M* ± *SD*)	(*M* ± *SD*)	(*M* ± *SD*)
2	Narrative	0	-	-	-	-	-
2	Report	5	5.2 ±1.8	4.5 ±0.8	4.6 ±0.9	3.0 ±1.8	3.3 ±1.0
2	Explanation	30	5.4 ±1.3	3.9 ±1.0	3.4 ±0.9	2.8 ±1.4	3.0 ±0.7
3	Narrative	6	5.4 ±0.9	3.6 ±0.7	3.5 ±0.5	2.7 ±0.9	3.1 ±0.7
3	Report	24	5.4 ±1.9	3.6 ±1.6	3.2 ±1.0	3.1 ±1.7	3.4 ±1.3
3	Explanation	29	5.4 ±1.3	3.9 ±1.0	3.7 ±0.7	3.2 ±1.3	3.2 ±1.0
4	Narrative	0	-	-	-	-	-
4	Report	42	7.9 ±2.0	5.7 ±1.7	5.9 ±2.0	4.7 ±1.8	3.7 ±1.2

Publisher /Author grade	Genre	Number of passages analyzed	Gunning Fog	Flesch-Kincaid	Fry	Auto-mated Reading Index	Lexile
4	Explanation	24	7.2 ±2.5	5.2 ±1.8	5 ±1.4	4.2 ±1.8	4.0 ±1.5
5	Narrative	0	-	-	-	-	-
5	Report	9	7.1 ±1.5	5.3 ±1.3	5 ±1.1	3.7 ±1.8	3.9 ±1.2
5	Explanation	48	6.8 ±2.2	5.8 ±1.5	5.6 ±1.9	4.3 ±1.8	4.0 ±1.3
6	Narrative	0	-	-	-	-	-
6	Report	9	9.7 ±2.0	8.0 ±2.0	7.7 ±0.5	7.6 ±2.2	6.7 ±2.3
6	Explanation	30	7.9 ±2.0	6.3 ±2.0	6.4 ±1.7	5.1 ±2.2	4.7 ±1.9

Table 9. Means of genre-specific readability calculations by grade level (online articles)

Publisher /Author grade	Genre	Number of passages analyzed	Gunning Fog	Flesch-Kincaid	Fry	Auto-mated Reading Index	Lexile
			(*M* ± *SD*)	(*M* ± *SD*)	(*M* ± *SD*)	(*M* ± *SD*)	(*M* ± *SD*)
2	Narrative	0	-	-	-	-	-
2	Report	18	6.4 ±1.6	4.7±1.6	4.3 ±1.8	3.7 ±1.8	3.2 ±0.9
2	Explanation	38	6.8 ±2.4	5.4 ±2.2	5.1 ±2.1	4.6 ±2.8	4.3 ±1.9
3	Narrative	3	6 ±1.3	4.2 ±1.0	4 ±0	3.4 ±0.3	3.4 ±0.9
3	Report	18	6.8 ±2.2	5.4 ±2.2	5.7 ±2.3	5.1 ±2.4	4.6 ±2.0
3	Explanation	36	10.6 ±4.1	8.9 ±3.8	8.1 ±3.3	8.8 ±4.3	7.3 ±2.7
4	Narrative	0	-	-	-	-	-
4	Report	27	7.9 ±3.6	6.6 ±3.7	6 ±2.8	6.0 ±4.1	4.6 ±2.5
4	Explanation	41	7.7 ±3.2	6.0 ±2.8	5.4 ±2.4	5.3 ±3.2	5.0 ±2.4
5	Narrative	0	-	-	-	-	-
5	Report	12	6.6 ±1.7	5.5 ±1.4	5.8 ±0.9	5.0 ±1.8	3.5 ±0.7
5	Explanation	37	8.3 ±3.8	7.3 ±3.6	6.4 ±2.3	6.3 ±4.3	5.2 ±2.6
6	Narrative	0	-	-	-	-	-
6	Report	32	6.7 ±2.6	5.1 ±2.3	4.8 ±2.2	4.4 ±2.4	3.8 ±1.9
6	Explanation	14	6.2 ±1.2	4.6 ±1.0	4.8 ±0.8	3.3 ±1.5	3.2 ±0.9

Discussion

This study focused on science-based text in elementary literacy readers, trade books, and online articles to ascertain how text readability measures compare when mapped onto grade-specific science curriculum standards and whether or not there are differences among readability measures and text sources (e.g., literacy readers, trade books, online articles). Not surprisingly, there was disparity in the grade-specific passages and a lack of consistency among the formulae. The outlier formula was the Lexile, likely due to its purported distinction to measure text difficulty along with reader ability as validated with standardized tests, criterion-based assessments, and basal readers (Metametrics, 2015). When the text types are considered, it appears that the variability in sources (i.e., various trade books; online articles) and genres (i.e., narrative, report, explanation) contributes to a lack of controlled readability (Fazio & Gallagher, 2014; Gallagher, Fazio, & Ciampa, 2013). Such text sources originate from several publishers, authors, and platforms, and although this variety is engaging for students, it may pose instructional challenges for teachers. In particular, the presentation of online text is represented in both words and images, making readability a conjectural construct.

Content area literacy pivots on using texts for different purposes (Moss, 2002). Access to appropriate texts that represent different perspectives and presentations (such as print and digital) is integral to sound literacy instruction in the 21st century. Teachers have a multiplicity of texts to choose from, and this can be an overwhelming instructional decision. For decades, the International Literacy Association (2010) has encouraged teachers to be critical consumers of texts and evaluate a range of texts. This allows teachers to ensure that in order to become fluent, versatile readers, students have access to a variety of texts. Moreover, teachers need to make appropriate text choices to support students as they learn to comprehend what they read in science texts. We engaged in this investigation because of a lack of research in the area of readability in science-based print and online text. Teachers rely on authors and publishers to accurately represent the readability of text. The results of this study suggest that when making instructional choices about science-based text, teachers need to attend to not only the type of texts but also the inconsistencies in the readability of the texts.

Traditionally, elementary teachers have relied on basal or literacy readers as a resource for helping students learn to read and textbooks for reading to learn. Specifically, basal readers, that include few informational text passages, have been the resource of choice in 85% of elementary classrooms (Claridge, 2012; Moss, 2005). Textbooks are often relegated to short readings for specific knowledge gaining purposes. Yet it has been well established that science textbooks contain a number of unfamiliar, technical vocabulary that are not frequently reinforced (Cohen & Steinberg, 1983; Walton, 2002). Contemporary teachers may tap into vocabulary supports such as word clouds (pre-defining challenging vocabulary) and guided reading activities (Smith & Mader, 2015) to help reinforce the learning of unfamiliar words. This is important as Walton (2006) investigated publishers' readability claims with trade books and textbooks using several different forms of readability tests, and found that the text choices were at a much higher level than the publishers' literature had claimed. This finding is similar to that in the present study. This overstatement is concerning given the reliance that teachers have on publishers' expertise.

Moreover, there should be significant attention devoted to the instructional use of freely accessible online text that has not been levelled for readability. In our study, the readability of online texts was unstable and not often correlated to other measures. Teachers often source out these texts based on a topic, concept, or theme that relates to a unit of study, which often does not correlate to grade level. Even though the findings of the present study suggest the inherent inconsistencies in matching online articles to curriculum content, teachers should not avoid using such texts. Hiebert (2013) suggests that teachers should capitalize on the tendency for online articles to increase students' background knowledge and interest in reading information text.

Informational text and genres such as reports are commonly used in science education. The present study's results suggest that educators pay attention to the readability of these types of texts. Concerning the awareness of the pronounced readability challenges of such informational texts, Yore (2004) has suggested instructional strategies for integrating science and literacy. Among these recommendations is the idea of using text structure to comprehend ideas, and conceptual networks to sort them.

Implications for Practice

There are unique qualities (e.g., text elements, genre, and vocabulary) inherent in science-based texts that contribute to anomalies in readability correlations. The characteristics of these texts are such that scientific vocabulary bolsters the complexity of the text. As well, some of the variables used to calculate the indices may more accurately reflect the qualities of science-based text (e.g., words with more than three syllables). This is a call to authors, editors, and publishers to be informed about the most appropriate readability measures for science-based text. Teachers should be aware of the limitations of readability indices and be well informed when making instructional decisions based on the most appropriate readability measures for content area texts—teachers are the last line of text scrutiny for instructional appropriateness. Educational researchers should consider investigations into finding the most reliable index for the various genres of science-based text.

Teachers should take full advantage of the plethora of alternative texts that are available for content-area instruction that might appeal to their students' interests, background knowledge, and experience. Atkinson, Matusevich, and Huber (2009) have proposed a rubric to assist teachers in making informed decisions about science trade books for use in classrooms. Criteria in the rubric relate to science content, genre, writing style, illustrations, readability, and text features. We contend that a supplement to this rubric should be a further consideration of the way in which readability has been calculated given the source of science text (i.e., print-based or online text).

Elementary teachers might consider the impact of readability on instructional decision making and strategy instruction. Vocabulary and reading comprehension strategies should be taught in the context of science learning. Teachers should begin by activating prior knowledge and identifying vocabulary that are essential for understanding key concepts and reinforce use of these words throughout the content area teaching (Dougherty Stahl & Bravo, 2010; Fenty & Barnett, 2013). Word knowledge is solidified with multiple exposures in meaningful learning contexts, and such learning contexts should include interacting with science in the real world (Preczewki, Mittler, & Tillotson, 2009). Dialing into domain knowledge enhances vocabulary understanding (Fisher et al., 2009) and comprehension (Moss, 2005) as well as reading fluency and motivation (Guthrie, Anderson, Alao, & Rinehart, 1999). These strategies are especially fundamental for the teaching of science.

Teachers should continue to provide explicit strategies for reading fluency and vocabulary access of predominant text genres in science (e.g., reports). In particular, explicit teaching of text genres, including the skills of identifying audience and purpose, is essential to enhance the literacy skills of diverse language learners and struggling readers (Fenty & Barnett, 2013). Visual literacy is an integral skill as well, and students benefit from direct comprehension instruction on how to decipher and extract meaning from diagrams and graphics in science text (McTigue & Flowers, 2011). Specifically, word text can be supported by images when the content or vocabulary is challenging (Liang et al., 2013).

An effective instructional method is close reading (Lapp et al., 2013), which encourages students to focus on details while analyzing the language used, structure, images, arguments, and ideas within the text. During close reading, students must read and interrogate at all levels: word, sentence, paragraph, image, and whole body of text. Engaging prior knowledge before a close reading of science text is helpful, as students are likely to encounter content density and challenging claims. Questions should prompt students to search, synthesize, infer, and make judgements that are supported by text-cited evidence (Lapp et al., 2013). Close reading can be enhanced with technology by using multimodal hypertext commentary (Dalton, 2013). Digital means for posing questions and making text annotations is an accessible extension of close reading. Students may also engage through illustrating and audio recording their reactions and comments.

A second instructional approach that integrates both reading and writing in science is copy change, which supports individual students as they use a mentor text as a pattern for their own writing (Bintz et al., 2010). In science, students can read and learn from (appropriately levelled) texts, and then use them as models to communicate their own inquiry, investigation, or knowledge. Then students may use the structures and patterns of the mentor text as a framework to develop their own writing. In the publishing phase, students share and discuss their authored works, communicating their learning in science. Multimodal representations might be leveraged to share these expressions of student learning of science with text-to-speech options and web-based platforms.

Many teachers are implicitly working through the readability challenges that their students face by providing them with decoding strategies. Yet teachers would benefit from continued professional learning opportunities to explore readability and reliably use measures of text difficulty. Teachers also need time to moderate the subjective nature of readability formulae applications. In this context, teachers could collaborate using exemplars to determine text readability levels based on quantitative and qualitative factors and their students' characteristics and instructional tasks. As suggested by studies that examine the interplay between quantitative and qualitative measures of readability (e.g., Pitcher & Fang, 2007), determining a text level is a starting point where teachers should then consider the reader, the text, and the context. These considerations are excellent fodder for collaborative, collegial discussions among teachers. School districts should consider what professional learning opportunities exist to enhance elementary teachers' understanding of readability and instructional methods when using science content-area text.

Appendix A

(sample only, for complete listing please contact authors)

Trade Books

Grade 2		
Title	**Author**	**Genre**
1. Endangered Animals	McNulty, Faith	Explanation
2. Water as a Solid Frost	Frost, Helen	Report
3. What Is a Pulley?	Douglas, Lloyd G.	Report
4. Solid, Liquid, or Gas?	Hewitt, Sally	Explanation
5. The Frog	Crewe, Sabrina	Explanation
6. Amazing Materials	Hewitt, Sally	Report
7. Water as a Gas	Frost, Helen	Explanation
8. Living Things	Mason, Adrienne	Report
9. Snow Is Falling	Branley, Franklyn M.	Explanation
10. Down Comes the Rain	Branley, Franklyn M.	Explanation
Grade 3		
Title	**Author**	**Genre**
1. Plants Are Living Things	Kalman, Bobbie	Explanation
2. What's Inside Trees?	Kosek, Jane Kelly	Explanation
3. Amazing Plants	Hewitt, Sally	Explanation
4. From Seed to Plant	Gibbons, Gail	Explanation
5. Energy from the Sun	Fowler, Allan	Narrative
6. Amazing Magnetism	Carmi, Rebecca	Explanation
7. Tundra Food Webs	Fleisher, Paul	Explanation
8. Desert Food Webs	Fleisher, Paul	Explanation
9. Forest Food Webs	Fleisher, Paul	Explanation
10. Lake and Pond Food Webs	Fleisher, Paul	Explanation
Grade 4		
Title	**Author**	**Genre**
1. Coyote	Mattern, Joanne	Explanation
2. Look at Rocks and Fossils	Hantula, Richard	Report
3. Rattlesnakes	McDonald, Mary Ann	Explanation

4. What Is an Omnivore?	Kalman, Bobbie	Explanation
5. How a House Is Built	Gibbons, Gail	Report
6. Tundra Food Chains	MacAulay, Kelley	Explanation
7. Coral Reef Food Chains	MacAulay, Kelley	Explanation
8. A Look at Rocks	Kittinger, Jo S.	Report
9. Prairie Food Chains	MacAulay, Kelley	Explanation
10. Pulleys	Manolis, Kay	Report
Grade 5		
Title	**Author**	**Genre**
1. Science Experiments with Forces	Jackson, Dorothy M.	Report
2. Atoms and Molecules	Aloian, Molly	Explanation
3. Tornadoes	Burby, Liza N.	Explanation
4. Respiratory System	Jango-Cohen, Judith	Explanation
5. Charged Up	Bailey, Jacqui	Report
6. Nature of Matter	Claybourne, Anna	Explanation
7. The Digestive System	Johnson, Rebecca L.	Explanation
8. The Muscular System	Johnson, Rebecca L.	Explanation
9. Tornado Alert	Branley, Franklyn M.	Explanation
10. Save Energy	Barnham, Kay	Explanation
Grade 6		
Title	**Author**	**Genre**
1. Life in Outer Space	McDonald, Kim	Explanation
2. Star Factories	Jayawardhana, Ray	Explanation
3. Air and Weather	Davis, Barbara J.	Explanation
4. Amazing Electricity	Hewitt, Sally	Explanation
5. Biomes and Ecosystems	Davis, Barbara J.	Explanation
6. Science Experiments with Electricity	Nankivell-Aston, Sally	Explanation
7. Kids' Guide to Paper Air-planes	Harbo, Christopher L.	Report
8. A Forest's Life	Mania, Cathy	Explanation
9. Taking Flight	Krensky, Stephen	Explanation
10. Fantastic Flights	O'Brien, Patrick	Explanation

Appendix B

(sample only, for complete listing please contact authors)

Online Articles

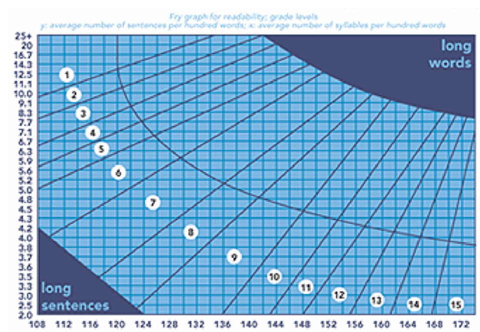
Grade 2			
Title	**Author**	**Genre**	**Source**
1. Dew	Lambeth, Ellen	Report	Ranger Rick
2. Tiger-r-r-r	Schleichert, Elizabeth	Report	Ranger Rick
3. Simple Machines	NA	Explanation	Kids InfoBits
4. Metamorphosis	NA	Explanation	Kids InfoBits
5. Scaly or Slimy? Learn about Reptiles and Amphibians	NA	Report	Weekly Reader
6. Mammals	NA	Explanation	Kids InfoBits
7. Water Cycle	NA	Explanation	Kids InfoBits
8. Life in a Deep Freeze: How Do Animals Survive the Arctic's C-c-cold Winters?	Markle, Sandra	Explanation	National Geographic Explorer
Grade 3			
Title	**Author**	**Genre**	**Source**
1. Going Green: Students at a Colorado School Grow Their Own Vegetables	Kraus, Stephanie	Report	Time for Kids
2. Magnetism		Explanation	HowStuffWorks.com
3. How Venus Flytraps Work	Meeker-O'Connell, Ann	Explanation	HowStuffWorks.com
4. Adventures of Ranger Rick	Marshall, Jody	Narrative	Ranger Rick
5. Best Buddies	Churchman, Deborah	Narrative	Ranger Rick
6. Gravity and Inertia		Explanation	http://www.science-monster.com/physical-science/gravity_inertia.html
7. Dig into Worms	Churchman, Deborah	Report	Ranger Rick
8. Thank a Tree!	Dixon, Norma	Report	Ranger Rick

Grade 4			
Title	**Author**	**Genre**	**Source**
1. Bats: Loss of Habitats and Roosts	NA	Explanation	Kids InfoBits
2. Mach 101: Just How Fast Is the Speed of Sound? (Space Aviation)	NA	Report	Boys' Life
3. Sound	NA	Explanation	Science Weekly
4. Panda Problems! Giant Pandas Are in Trouble	NA	Report	Weekly Reader
5. No More Gorillas? Hunting and Disease Are Putting These Gentle Giants at Risk	McClure, Laura	Report	WR News
6. Wheels, Levers and Pulleys	Kelley, S. Allyn	Explanation	Boys' Quest
7. 5 Big Problems Facing the Earth (Save the Planet!)	Gordon, David George	Report	National Geographic Kids
8. Wheels and Gears	NA	Explanation	Science Weekly
Grade 5			
Title	**Author**	**Genre**	**Source**
1. The Human Skeleton	NA	Explanation	Weekly Reader
2. Bone Up on Your Skeletal System!	Pickett, Anola	Explanation	Children's Digest
3. Bones and Skeleton	NA	Explanation	Kids InfoBits
4. Bones on the Go!	NA	Explanation	WR News
5. Organs	NA	Explanation	Kids InfoBits
6. Digestive System	NA	Explanation	Kids InfoBits
7. Respiratory System	NA	Explanation	Kids InfoBits
8. The Beat Goes On: Your Heart Beats 100,000 Times a Day	Nancy Finton	Explanation	National Geographic Explorer
Grade 6			
Title	**Author**	**Genre**	**Source**
1. Rain Forests: What Are Rain Forests?	Jackson Kay, & Parks, Peggy J.	Explanation	Kids InfoBits
2. First Flight	Dykstra, Christiann	Report	Cobblestone
3. Static Electricity and You	Lyer, Rani	Report	Boys' Quest

4. Is Our World's Natural Diversity in Danger?	Laue, Susan K.	Report	Current Health
5. America: From Space	NA	Report	National Geographic Explorer
6. Jupiter: The Moon King	Geiger, Beth	Explanation	National Geographic Explorer
7. The Sun: Our Stormy Star	Downey, Fran	Explanation	National Geographic Explorer
8. Moon Mission: Nearly 40 Years Ago, Americans Walked on Earth's Moon for the First Time	Downey, Fran	Report	National Geographic Explorer

Appendix C

Readability Indices

Indices	Mathematical Computation	Notes
Gunning Fog	0.4 x ((W / S) + (PSY / W x 100))	PSY- total polysyllabic words (words with 3 or more syllables) S - total sentences W - total words
Flesch-Kincaid*	0.39 x (W / S) + 11.8 x (SY / W) - 15.59	S - total sentences SY - total syllables W - total words
Fry	Count the number of sentences and the number of syllables in a 100-word passage. Plot a dot where the two variables intersect. The area where the dot is plotted signifies the approximate reading grade level	
Spache*	(0.121 x (W / S)) + (0.082 x (UDW / W) x 100) + 0.659	S - total sentences UDW - total unique difficult words not in the Spache Word List W - total words
Dale- Chall*	(W / S x 0.0496) + (DW / W x 100 x 0.1579) + 3.6365	DW - total difficult words (based on the 3,000 Dale-Chall Word List) S - total sentences W - total words
Coleman-Liau*	(5.89 x (C / W)) - (0.3 x (S /W))- 15.8	C - total characters in words S - total sentences W - total words
Automated Reading Index (ARI) *	(4.71 x (C / W)) + (0.5 x (W / S)) - 21.43	C - total characters in words S - total sentences W - total words
SMOG*	3.1291 + (1.043 x square root (PSY / S x 30))	PSY- total polysyllabic words (words with 3 or more syllables) S - total sentences

*Computer applications of formulae were used for the calculations.

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