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The Effect of Digital Textbooks on Comprehension Performance in Inclusive Science Classrooms

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Abstract

The purpose of this study was to examine the impact of digital textbooks versus traditional textbooks on comprehension performance and application in secondary inclusive classrooms. The sample comprised of 121 sixth grade students, in six science class periods, which were divided into three groups. Using a control/treatment quasi-experimental counterbalanced design, the study was conducted through two phases; in phase 1, group 1 was the treatment (received the digital textbook), while groups 2 and 3 were the control (received the traditional textbook); in phase 2, groups 1 and 2 switched, while group 3 remained in the control group. Across both phases, there was no statistically significant difference in comprehension performance between both groups. In regard to application, there was also no statistically significant difference between groups in Ecocolumn project, but there was a significant difference in regard to Food Web project. The limitations and implications of the study are discussed.

Keywords: *Digital Textbooks, Reading Comprehension, Inclusive Classrooms, Secondary Students, Science Content.*

Introduction

The inclusion of all students in general education classrooms has globally been a critical initiative for many education systems over the past decades. Since the movement of inclusive education, all students (including struggling learners and those identified with disabilities) are required to meet the demanding standards and learn essential skills of such setting (Gersten et al., 2006). However, those students commonly encounter serious challenges with accessing content, especially when it comes to reading-related tasks. These issues become more complicated at the secondary level since the reading expectations and content-based demands are higher. Given students at the secondary level start to read to learn instead of learning to read, struggling learners and students with disabilities (SWDs) usually perform less than their typically developing peers in standardized achievement tests and reading (Seifert & Espin, 2012), particularly reading comprehension-related tasks (Ciullo & Reutebuch, 2013; Solis et al., 2012).

Reading comprehension challenges have been a major roadblock in the path of success for secondary students with/without disabilities (Gajria et al., 2007; Solis et al., 2012) since academic success not only depends on students' ability to read text but understanding what they read (Swanson et al., 2012). Based on a meta-analysis of 180 effect sizes from 23 studies, Gilmour (2019) found SWDs performed 1.17 standard deviations (more than 3.3 years reading achievement gap) below their peers without disabilities. While reading, secondary struggling readers and SWDs commonly encounter the following issues: relating new knowledge to prior

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knowledge, connecting meaning to words, inferring the main concept, excluding unimportant details, retaining information in short-term memory, recalling information during assessments, and actively monitoring their comprehension (Dexter & Hughes, 2011; Kaldenberg et al., 2015; Watson et al., 2012). The aforementioned challenges negatively affect those students' ability to comprehend what they read (Ciullo & Reutebuch, 2013), and ultimately their overall academic outcomes.

Other factors can further complicate secondary SWDS' reading experience and comprehension. First, general teachers are not well-prepared to support SWDs at the secondary level (Scammacca et al., 2013). Therefore, those teachers are not commonly equipped with robust theoretical and practical knowledge to support secondary inclusive classrooms, especially when it comes to helping *all* students to access and understand texts. The other factor is the textbooks' complexity. Although textbooks are the main source of teaching at secondary education (Seifert & Espin, 2012), multiple studies (e.g., Berkeley et al., 2010; Gajria et al., 2007; Mason & Hedin, 2011) found that secondary textbooks contribute to unneeded complexity of comprehension due to their complicated structure and features. Since textbook content is not accessible for all students in inclusive settings, secondary struggling learners and those with disabilities consequently perform lower than their peers, specifically in comprehension-related tasks.

The aforementioned reading comprehension-related challenges and other factors (e.g., teacher unpreparedness for secondary inclusive settings, textbooks complexity) encouraged concerned researchers to investigate the effectiveness of strategies on reading comprehension performance of secondary SWDs and struggling learners. These empirical studies have provided a number of effective interventions that can improve reading comprehension of SWDs. These strategies include but not limited to: graphic organizers (e.g., Kim et al., 2004), computer-based graphic organizers (e.g., Ciullo & Reutebuch, 2013) summarization and main idea identification (i.e., Gajria et al., 2007), mediating student learning (i.e., Gersten et al., 2010), self-monitoring (e.g., Kim et al., 2012), peer tutoring (Author, 2018), and computer-assisted instruction (e.g., Stetter & Hughes, 2010).

Theoretical Farmwork

Although the past two decades of reading-related literature has provided many effective comprehension interventions for secondary students in inclusive settings, we still need more *innovative technology-based solutions* to address reading challenges in secondary inclusive settings. Technology, without a doubt, has become an integral part of the society, and with its advancement, accessing content books has socially changed. Therefore, educational systems have started to adopt technology-based solutions into educational environments (Engbrecht, 2018). The goal of such practice is to enable all students to access content digitally and improve their learning experiences. One of these technology-based solutions is digital textbooks. Throughout the years, traditional books have held their significance as they the most critical aspect of educational and learning environment, yet they can be a promising solution that may enable students to access content digitally and ultimately enhance their educational outcomes (Lee et al., 2023; Orey et al., 2013).

Digital Textbooks

Since their introduction, educational stakeholders have perceived digital textbooks as a promising medium for instructors and learners in inclusive educational settings. Therefore, many education systems have initiated policies to adopt digital textbooks into their schools

(Rodríguez-Regueira & Rodríguez-Rodríguez, 2022). Digital textbooks are a progressively evolving technology-based solution (Turel & Sanal, 2018). Roughly two decades ago, digital textbooks were created by transitioning content from printed books to digital format (e.g., e-books, PDF files). They were simply digital versions of the existing printed textbooks, which only enabled for minimal interaction between the user and content (Jang et al., 2016).

As they were integrated into educational settings, digital textbooks had evolved to reflect and meet the need of diverse students in inclusive settings. Therefore, the new generation of digital textbooks do not only include digitized content, but also various user elements, multimedia functions, and communication features. For example, users can highlight critical text, take notes, search for further information, and look up word definitions. Multimedia functions comprise of photos, videos, and recorded audio materials. Communication features are functions that enable interactions between teachers and students in online settings; these interactions can occur through allowing teachers to post class-related materials and enabling students to participate, comment on discussions, upload assignments, and receive feedback (Im, 2024; Sun & Pan, 2021).

Since the current digital books have more sophisticated functionalities and advanced features, they have become more interactive, engaging, flexible to use, quickly adapt to users' needs and progress (ElAdl & Musawi, 2020; Jang et al., 2016; Kim & Kim, 2022), and for being a sustainable aspect of education since their cost effectiveness (Al Mulhim & Zaky, 2023). Therefore, they have the potential to address secondary SWDs and struggling learners' reading-related challenges, make the text content more accessible, and improve their overall reading experiences, which ultimately enhance their reading comprehension performance.

Literature Review

Multiple research teams have analyzed, examined, and explored the impact of digital textbooks on academic achievement of K-12 students with/without disabilities. For example, Berkeley et al. (2015) meta-analytically analyzed 27 group intervention studies that investigated the impact of interventions utilized to deliver digital versus traditional textbooks on reading comprehension of K-12 students with/without disabilities. They found a small weighted mean effect size of instructional practices designed to provide basic access to text (*ES* = -.03, range -.49-1.18) and a moderate effect size for instructional practices used to provide access to digital text (*ES* = .51, range -.35-1.57). Consistent findings were determined when it came to student type (with disabilities vs. without) and grade level (elementary vs. secondary).

Based on a comprehensive review of 84 studies that examined the effects of digital environments on K-12 students' reading performance, Cheung and Slavin (2012) found larger positive significant effects of digital environments compared the traditional ones, although the average effect size was comparatively small. Clear differences were found between studies regarding effect sizes, which could be explained by the characteristics of the environments and education level. The intensity of the intervention (hours per week), for example, was associated with larger effects. Digital environments seemed more effective and has larger effects for secondary students than primary students as well as when teachers were keenly involved in using these environments by adjusting their teaching practices to the environment and tailoring their instruction to complement the content provided in the learning environment (Lysenko & Abrami, 2014; ter Beek et al., 2018).

More recently, various studies examined the effects of digital textbooks on students with/without

disabilities' academic achievement. Krieger (2017), for instance, investigated the effects of using digital versus printed textbooks on comprehension performance of 31 high school students with various disabilities. In addition, in a fifth grade science class, Song et al. (2017) examined the effects of using digital textbooks versus traditional textbooks on academic achievement of 101 struggling learners. The results of both studies revealed that students who used the digital textbooks significantly outperformed the ones who read via the traditional textbooks. Other studies have also documented significant positive effects of using digital textbooks on academic achievement across subjects, such as English (e.g., Kim & Kim, 2022), mathematics (e.g., Kim & Yun, 2021; Turel & Sanal, 2018), and science (e.g., Metcalf et al., 2023).

On the other hand, some meta-analyses, reviews, and studies found no significant difference between learning outcomes of students using digital versus traditional (printed) textbooks. For example, Delgado et al. (2018) conducted a meta-analysis to analyze 54 studies published between 2000-2017 that compared the effects of reading on paper versus digital devices. They found that generally students in who read on paper significantly outperformed the ones reading via digital textbooks (Hedge's g=−0.21; dc=−0.21). They also indicated that throughout the studies the performance of students reading on paper was consistent. In addition to the aforementioned meta-analysis, Mangen et al. (2013) investigated the impact of reading via digital versus traditional textbooks on reading comprehension of 72 10^{th}-grade students. The results revealed that students reading via printed texts significantly outperformed students reading texts digitally on reading comprehension tests.

Svensson et al. (2021), more recently, examined the effects of assistive technology-based applications on reading performance of 149 secondary SWDs. They also found that comprehension performance did not significantly differ between groups reading via digital devices versus the ones reading via traditional textbooks. The abovementioned results can be attributed to many factors, such as digital textbooks require more time to read and navigate than traditional textbooks (Chulkov & VanAlstine, 2013; Daniel & Woody, 2013), which can slow the reader's mental representation of the text (Engbrecht, 2018; Mangen et al., 2013), lack of technology knowledge (Grönlund et al., 2018), and preference of using traditional textbooks more than the digital ones (Im, 2024; Johnston et al., 2015; Turel & Sanal, 2018).

Rationale and Significance

In order to improve student outcomes, which has been the primary goal of many educational systems (Lee et al., 2023; Lim et al., 2022; Wijaya et al., 2022), we need to identify ways that enhance their ability to comprehend what they read. Reading comprehension skills are not only critical for future educational and career opportunities but also for future life success (Vaughn & Barnes, 2023). On the other hand, not being able to comprehend or understand texts can hinder students with/without disabilities from attaining future academic or job-related opportunities (Seidenberg, 2017). Therefore, reading comprehension is a vital and fundamental life skill that predicts the life-long success of all school students, so educational stakeholders must continuously examine and identify practices that have the potential to enhance such skill, especially in inclusive settings.

The findings across the literature investigating and comparing the effects of utilizing digital versus traditional textbooks on reading performance of K-12 students with/without disabilities are mixed. Therefore, it is questionable whether digital textbooks can address reading challenges of secondary students in inclusive settings. However, digital textbooks are still promising technology-based solutions. In addition, given secondary students continue to be challenged by

the demands of content-based reading, innovations, like digital text, need to be considered as part of a continuum of solutions and examined through empirical studies. *With that, we need to utilize frameworks that can leverage the integration of technology-based solutions, including digital textbooks, into inclusive classrooms*. One of these frameworks is Universal Design for Learning (UDL).

With its guidelines, including multiple means of engagement, multiple means of representation, and multiple means of action & expression (see Figure 1), UDL is a framework that enables educators to design accessible, inclusive, equitable, and challenging learning environments. The goal of UDL is to promote inclusive education for all students (including those with disabilities and struggling learners) through reducing barriers, enhancing engagement, creating and rigorous meaningful learning activities. This ultimately supports learner agency, meaning learners can have control over their own learning and actively participate choices related to their own learning goals (CAST, 2024).

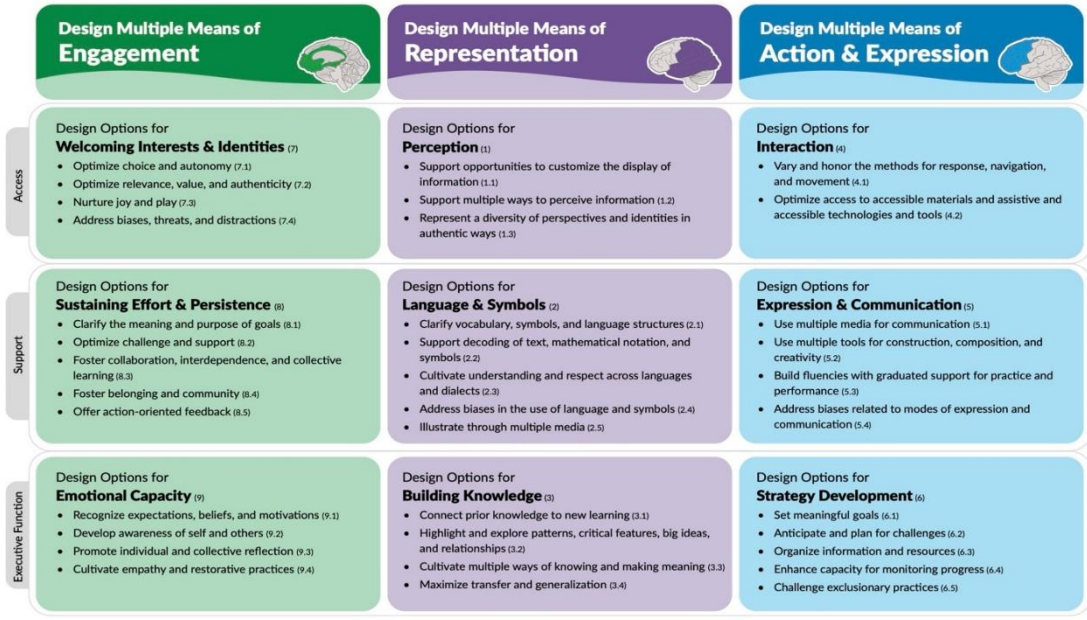

Figure 1: Universal Design of Learning Guidelines

Source: CAST (2024)

Since this study is taking place in inclusive settings, we will utilize UDL's guidelines, specifically *multiple means of representation* in order to address reading comprehension challenges for all students. Teachers can provide options for perception, language & symbols, and comprehension (CAST, 2024). In other words, instead of using texts as the primary content tool, teachers can represent ideas, content, and related materials through visual supports, media, audios, videos, condensed text, etc. Using UDL's guidelines into the design of digital textbooks may not only promote the mission of inclusive education but also can create innovative and in-depth learning environments that enable all learners to overcome their learning obstacles, especially when it comes to the "essence of reading": reading comprehension.

Purpose and Research Questions

While the findings of digital textbooks to improve reading-related literature are mixed, the advances in what educators can develop and integrate, such as digital textbooks, need to be further examined. Therefore, the purpose of this study was to understand how digital textbooks would impact reading comprehension and application in *inclusive classrooms* through answering the following questions:

1. What is the difference in the reading comprehension performance of sixth grade students using traditional textbooks versus a digital textbook?

2. How does reading from the textbook compared to the digital textbook affect the sixth grade students' application?

3. What is the difference in the reading comprehension performance of sixth grade students with/without disabilities using traditional textbooks versus a digital textbook?

Methods

Design

The study used control/treatment quasi-experimental counterbalanced design to compare the effects of a digital textbook to a traditional textbook. For our purposes, we formed a *convenience sample* of three groups (one treatment and two control) of sixth grade students in six inclusive science classrooms. The groups participated in two phases. In phase one, group 1 was the treatment group (received the digital textbook) while group 2 and three 3 the control group (received the traditional textbook). In phase two, groups 1 and 2 switched books while group 3 remained as a control group accessing content via the traditional textbook. Thus, in phase two, group 2 became the treatment group *(*received the digital textbook), while groups 1 and 3 were the control group *(*received the traditional textbook).

Treatment-control groups were identified based on the sixth grade science teacher's perspective of class ability and the make-up of struggling learners, those identified with disabilities, and those who speak ESL. For example, group 3 had the smallest percentage of struggling learners and no students identified with a disability, and thus it was determined to maintain control status for both phases of the study. Likewise, the remaining four class periods had a varied student population and identified by the science teacher as in need of additional supports to enhance their learning. Thus, treatment-control classes were determined in collaboration with the science teacher who informed the author on class make-up based on the stated categories.

Setting and Participants

The stud took place in a US suburban, Midwestern middle school. The school had implemented a rotation blended learning model, meaning that a 1:1 device policy that provided all students with iPads for their academic use. A total of 121 sixth grade students, across six science class periods, participated in the study. Of the 121 students, 56 were male and 65 female. Students were grouped by the class periods they attended in the inclusive science classroom. The first group included class periods 4 and 6 (treatment-control) and had a total of 45 students. The second group (control-treatment) had 39 students representing class periods 5 and 7. The third and final group (control-control) had 37 students representing class periods 3 and 8 (See Table 1).

Phases	Intervention (Digital Textbook)	Control (Traditional Textbook)
Phase 1	Group 1	Groups 2 & 3
	45	76
Phase 2	Group 2	Groups 1 & 3
	39	82

Table 1: Study Design (Total= 121 Students)

Table 2 offers a breakdown of the 121 students who participated in the study. In addition, two teachers participated in the study. One general education teacher with 13 years of experience taught all six sections of sixth grade Life Sciences and implemented the study. The other teacher, who only assisted with the development of the digital textbook, was a special education teacher known for her experience with digital text and technology. She had seven years of teaching experience at the time of the study.

Characteristics	Total *n* = 121
Ethnic Group White African-American Asian Hispanic	 101 5 8 7
Disability Type LD ADD SLD Blind Students	 8 1 1 1
Students who speak ESL	7
Struggling Learners	20

Table 2: Study Participants

Note. LD = Learning Disabilities, ADD = Attention Deficit Disorder, SLD = speech language disorders, ESL = English as a Second Language

Materials

Working with the sixth grade science teacher, a six-week unit on Ecology was identified from the *Life Science* curriculum. The Ecology unit was separated into four equal parts for the purpose of this study with each part including an assigned reading, in class presentations, student led activities, and then the completion of a ten-question quiz prior to the next unit section. The assigned readings, which began each of the four parts of the unit, were identical in content focus, the essential elements on Ecology (as identified by the science teacher) and state science standard alignment. Both the control and treatment group were assigned the material on the same day and offered similar time in class to review the materials independently.

Textbooks

Both the control and treatment class periods were assigned readings on Ecology prior to each of the four lessons over a six-week period. The control classes were assigned readings in the Life Science textbook, a resource used throughout the academic year. The traditional textbook, which was adopted for district-wide sixth grade science, is print-based with text at grade appropriate reading level with accompanying pictures, figures, tables, call-out vocabulary, bold and underlined features to highlight key vocabulary or concepts, and other features typical of many textbooks today.

Classes assigned to the treatment classes were provided a digital book available in iBook on the iPad Air. Each of the four Ecology readings followed an identical design and development process. The basic design of the digital book included many of the traditional textbook features including text, images, pictures, tables, figures, and highlighted keywords. For the digital textbook, the assigned text aligned with state science standards and the critical elements of the Ecology unit. Unlike the traditional textbook, the digital books streamlined the amount of text focusing on the essential elements of the Ecology unit deleting secondary information that was supplementary to the teacher's focus for this unit. Thus, the digital book had less text per lesson, and the essential elements of text were defined by the science teacher.

While the remainder of the digital book aligned with the key features of the traditional textbook (e.g., images, keywords), multimedia elements were utilized to further enhance the digital text. These aspects included embedded videos, the inclusion of multiple (rather than one) images and pictures, highlighted keywords, and review of critical ideas and themes as the student progressed through the book. Participants also had the option of listening to the book through the text-to-speech option.

The Development of the Digital Textbook

The digital book was developed in collaboration with the sixth grade science and the secondary special education teachers. The process involved a seven-step sequence including development, review, editing, and further review to ensure an appropriate text aligned with the essential elements of the unit, state science standards, and the traditional text used throughout the academic year. It should be noted that each step attempted to integrate the first principle of Universal Design for Learning (UDL), multiple means of representation, and its affiliated guidelines and checkpoints (CAST, 2024). By filtering the digital text through this additional framework, the researcher and instructors intended to ensure further alignment to the needs of all learners.

The seven step development process included: 1) the science teacher identified the essential

elements (e.g., main ideas, key vocabulary) of the traditional textbook to consider for the digital textbook; 2) the special education reviewed for language aligning with the essential elements identified by the science teacher; 3) both teachers reviewed the digital textbook to ensure that the alignment to science was there and still approachable for all students; 4) the science teacher offered media suggestions along with the researcher; 5) the science teacher added some of the features suggested by the researcher; 6) the author completed the final stage of the development; and 7) the science teacher reviewed the digital textbook to confirm its applicability to all students in her class. This process of development was repeated with the four digital textbook sections that were representative of the four sections of the Ecology unit.

Instruments. Student comprehension performance was measured by three methods: pre-post multiple-choice quizzes, an end of the unit Food Web, and an end of unit Ecosystem. With the intent to measure reading comprehension, the quality of applications led by comprehending the content was also measured.

Development of Multiple-Choice Quizzes

To measure comprehension, the researcher constructed four pre-post multiple-choice quizzes (one per lesson) comprising 10 questions for each lesson. The multiple-choice quizzes were developed across a seven-phases design. First, the science teacher conducted 10 questions at the end of each section of the digital textbook, which initially were the original questions at the end of each section of the traditional. Second, the author reviewed previous the 10 comprehension questions already developed by the sixth grade science teacher. These questions were either taken from the textbook or created to align with the essential elements of the reading that she reinforced in class through lecture and activities. Third, the author constructed a 10-multiple-choice quiz aligned with the questions created at the end of the digital textbook sections. Fourth, the science teacher and author then reviewed each question to determine its alignment to the essential elements of the text and what the teacher had determined to be critical for all readers. Questions not aligned with the essential elements were deleted. Fifth, the author reviewed each of the remaining questions and edited the question and affiliated answer to ensure an appropriate reading level. Sixth, the special education teacher along with the author reviewed the questions and revised for language considerations to ensure the understanding of the questions for all learners including SWDs as well as students who speak ESL. Seventh, once the test items were finalized, two versions of the test were made (same questions in a different order) to function as the pre-post test set for each lesson. It should be noted that the author contributed greatly to the review process since his expertise with special education and reading comprehension skills as well as his experience with speaking ESL.

Development of Lab Product Rubrics

To determine comprehension and application of the reading content, two end of unit measures were developed: Ecocolumn and Food Web rubrics. For the purposes of this study, an established classroom measure that was previously used by the teacher and aligned with the state standards and the essential elements determined by the science teacher according to the class and district guidelines for the science content. Developed through a five-stage iterative design process, the rubrics were created based on previously used rubrics and reviewed by the sixth grade science teacher, the author, and the special education teacher. First, the researcher requested copies of the Ecocolumn and Food Web assignments from the science teacher. After the assignments were shared, the researcher constructed the rubrics based on the shared assignments and expectations. The researcher shared the rubrics with the science and special

education teachers to get their feedback. Fourth, the teachers offered feedback to the author. Finally, the researcher modified the rubrics based on the shared feedback.

Procedure

The science teacher introduced to students the first two sections of the Ecology unit, iBook Author, and how to navigate it. All students (n= 121) took the pre-multiple-choice quiz before each of the Ecology unit's four sections. Group 1 (treatment group) read the first two sections via the digital textbook, but groups 2 and 3 (control group) read via the traditional textbook. All students participated in classwork, which included guided lectures, note taking, group discussion, and lab activities aligned with the readings. All students also took the post-multiple-choice quiz after reading each section of the Ecology unit. It should be noted the scheduling of pre- and post-quizzes throughout the study was consistent to ensure accurate results of the intervention.

In the first week of the intervention, the teacher introduced the Ecocolumn assignment and its expectations to students. The purpose of this assignment was to connect students practically to what they were learning throughout the Ecology unit. To accomplish this task, the science teacher divided students into groups of two or three students. The science teacher shared expectations of Ecocolumn project as well as tips to build and draw it accurately. Finally, all students started building their Ecocolumns. During building the Ecocolumns, students continued taking and writing their notes down of what they had observed.

Following the same procedures, groups 1 and 2 switched after three weeks, so group 2 became the treatment group (received digital textbook), and groups 1 and 3 became the control group (received traditional textbook). In the fourth week of the intervention, the science teacher introduced students to second project of this intervention: drawing Food Webs. The aim of this assignment was to determine whether students demonstrate an understating of what they learned during the first three weeks. To achieve this task, the science teacher divided students into groups of two or three students. The science teacher shared expectations of Food Web project as well as tips to build it accurately. Then, all students started building their Food Webs.

The science teacher introduced sections three and four of the Ecology unit for all students. All students took the pre-multiple-choice quiz before each of the Ecology four sections. Group 2 (treatment group) read the last two sections via the digital textbook, but groups 1 and 3 (control group) read them via the traditional textbook. Also, all students took the post-multiple-choice quizzes after reading each section of the Ecology unit. we should again note that we were consistent in scheduling pre- and post-quizzes throughout the study to ensure accurate results of the intervention. At the end of the intervention (the sixth week), students submitted their built and drawn Ecocolumns as well as their drawn Food Webs to the science teacher. Of the 121 participating students, only 99 students submitted their drawn Ecocolumns, while 114 students submitted their drawn Food Webs.

Data Collection

Multiple-Choice Quizzes

Four pre- and post- 10-multiple-choice quizzes were administered before and after each section of the Ecology unit. The researchers constructed these quizzes to measure students' understanding of the science content. The quizzes were printed out for students, so they used pencils to select the answers. Each question was scored with one point, which totaled ten points

per quiz. It should be noted that students took the same quiz as pre- and post-quiz (just the questions' order was changed).

Ecocolumn and Food Web Rubrics

The Ecocolumn rubric included six elements: (1) Biotic, (2) Abiotic, (3) Producers/ Consumers/ Decomposers (4) Title, (5) Drawn Elements, and (6) Labels. Each element was scored at the ranges of 0-5 points (total 30 points). The Food Web rubric contained five elements: (1) Organisms, (2) Labels, (3) Linkages, (4) Images, and (5) Neatness. Each aspect was scored between the ranges of 0-5 points (total 25 points). We created the aforementioned rubrics to measure the quality of students' drawn Ecocolumns and Food Webs.

To ensure reliability of the Ecocolumn and Food Web rubrics, 10 random samples from Ecocolumns and 10 samples of from Food Webs were randomly selected. The researcher and a research assistant independently scored the samples. The inter-rater reliabilities for the total score of both rubrics were correlated highly and excellent: Ecocolumn ($r = .98$) and Food Web ($r = .93$), respectfully.

Data Analysis

An analysis was conducted on the chapter tests to see if the treatment group outperformed the control group. The design of the study was such that for four consecutive sections, every section quiz was given as both a pretest and a posttest. The students who were in the control group for 1st phase were switched to the treatment group for 2nd phase and vise versa. Consequently, analyses were conducted on 1st phase separately from 2nd phase. Because the sections studied differed in difficulty and content, scores for the two pretests and the two posttests in each analysis were averaged together. This allowed for mixed model analyses of variance, with time 1 or time 2 as the independent within-subjects variable and group (treatment or control) as the between-subjects independent variable. Scores on the section quizzes (averaged between the four sections) acted as the dependent variable.

A second set of analyses centered on the scores for the Ecocolumns and Food Webs which served as the dependent variables for two independent t tests comparing students in the treatment group to students in the control group. Students who received the intervention for either 1st and 2nd phases were considered members of the treatment group. The results revealed that there were no significant differences between the two groups on either project. Because students in the treatment group differed in when they received the intervention (some received it for the first two units, while other received it for the last two units), a secondary analysis was conducted. An analysis of variance was conducted that compared three groups- the control group, a group receiving the treatment for the 1st phase, and a group receiving the treatment 2nd phase.

Results

In this study, we investigated three main questions. The first question was addressed to examine and compare the effects of a digital textbook to a traditional textbook on comprehension for sixth grade students. The second questions, which went beyond answering multiple-choice questions, was addressed to examine the effects of the digital textbook to the traditional textbook on students' applications. The third question was posed to compare the effects of digital textbooks on comprehension performance between students with/without disabilities. The total number of students who consented to participate in the study was 121 students. All students were included in the analysis for the chapter quizzes (n= 121). However, not all students were included in the

analysis of the application projects due to the incompleteness of their projects: Ecocolumn (n= 99), Food Web (n= 114).

Chapter Quizzes

A set of analysis was conducted on the chapter quizzes to determine if the intervention group outperformed the control group in the comprehension performance. The study was designed to include four consecutive units. A chapter quiz was given as both a pretest and a posttest. The students who were in the control group for units 1 and 2 were switched to the intervention group for units 3 and 4. Likewise, students in the intervention group for the first two units were in the control group for the last two units.

Consequently, analyses were conducted on units 1 and 2 separately from units 3 and 4. Because units differed in difficulty and content, scores for the two pretests and the two posttests in each analysis were averaged together. This allowed for mixed model analyses of variance, with 1st phase or 2nd phase 2 as the independent within-subjects variable and group (intervention or control) as the between-subjects independent variable. Scores on the chapter quizzes (averaged between the two chapters) acted as the dependent variable. Descriptive statistics for the two analyses are shown in Table 3.

		Pretest		**Posttest**	
Group	**N**	**Mean**	**SD**	**Mean**	**SD**
Units 1 and 2 combined Intervention	45	5.38	1.65	7.91	1.74
Control	76	5.80	1.71	8.15	1.74
Units 3 and 4 combined Intervention	39	4.41	1.63	5.99	2.30
Control	82	4.95	1.54	6.44	1.69

Table 3: Comparison of Groups on Chapter Quizzes

The analyses of variance for units 1 and 2 found no significant interaction between group and change in performance across the 1st phase, Wilks' Lambda F (1, 119) = .354, p = .55, partial eta-squared = .003. The analyses of variance for units 3 and 4 also did not find a significant interaction between group and change in performance across the 2nd phase, Wilks' Lambda F (1, 119) = .107, p = .74, partial eta-squared = .001. As shown in Figure 2, the comprehension performance of both the control and treatment groups increased about the same in the analysis of both the units 1 and 2 and the analysis of units 3 and 4 as well.

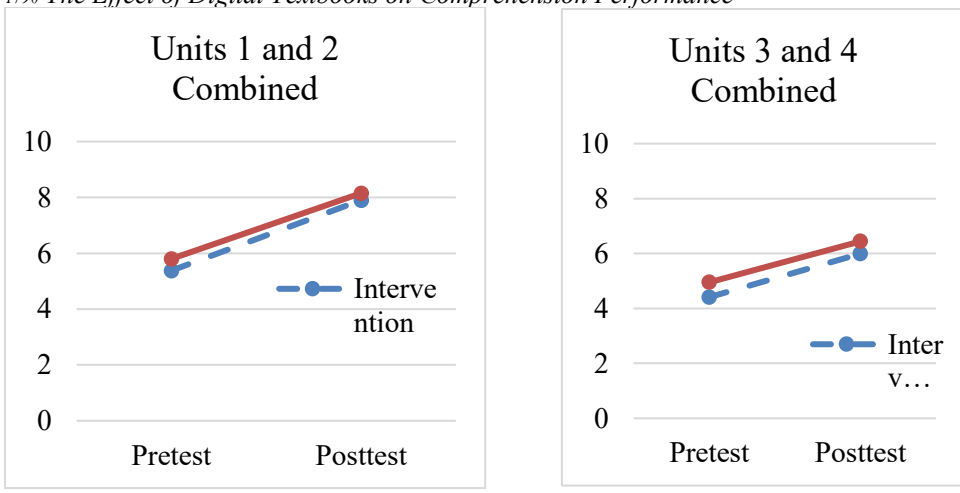

Figure 2: Scores of Chapter Quizzes

Ecocolumn and Food Web Applications

A second set of analysis was conducted to see if the treatment group outperformed the control group in the Ecocolumns and Food Web projects. The two projects were scored using rubrics that designed to measure the quality of Ecocolumns and Food Webs drawn by students. The scores of these projects served as the dependent variables for two independent t tests comparing students in the intervention group to students in the control group. For the purposes of these analyses, students who received the intervention for either the first two units or the second two units were considered members of the intervention group, and the students who were control throughout the study were considered as the control group. The results are shown in Table 4.

Group	**N**	**Mean**	**SD**	***T***	**df**	**p**
Ecocolumn						
Intervention	67	17.79	5.46	-.16	97	.88
Control	32	17.97	4.88			
Food Web						
Intervention	77	22.01	1.96	.43	57.68	.67
Control	37	21.81	2.52			

Table 4: Comparison of Groups on Applications

There were no significant differences between the two groups on either of the projects. Because students in the intervention group differed in when they received the intervention (some received it for the first two units, while other received it for the last two units), a secondary analysis was conducted. An analysis of variance was conducted that compared three groups- the control group, a group receiving the intervention for the first two units, and a group receiving the intervention for the last two units. This comparison between the control and treatment groups found no significant difference for the Ecocolumn project, $F(2, 96) = .19$, $p = .83$. However, we found a difference between the groups for the Food Web project, $F(2, 111) = 4.68$, $p = .01$, with a moderate effect size, eta-squared = .08. Follow-up t tests found that there was a significant difference was because the group that received the intervention later, during units 3 and 4 (M =

22.76), outperformed the group that received the intervention earlier, for units 1 and 2 (M = 21.33), p = .003. Neither intervention groups, however, outperformed the control group (M = 21.81).

Comparison of Student Differences on Chapter Quiz Performance

Groups of students were created based on designation as regular education (students without disabilities), students who speak ESL, or SWDs. The three groups' performances on each of the four quizzes (post-tests) are shown in Table 5. SWDs scored significantly lower than other students with a moderate effect size (Wilks' Lambda F = 2.18, p = .047, eta-squared = .06) (See Figure 3).

Chapter		18.1		18.2		18.3		19.1	
Group	≈ N	M	SD	M	SD	M	SD	M	SD
Regular Education	103	7.96	1.86	8.68	1.50	7.05	2.05	6.07	1.98
ESL	7	8.20	1.64	7.50	1.52	6.67	2.66	6.33	1.63
Disability	11	4.70	2.21	6.55	2.34	3.82	2.68	4.30	2.06

Table 5: Comparison of Groups on Chapter Quizzes

Note. ESL = students speaking English as a second language

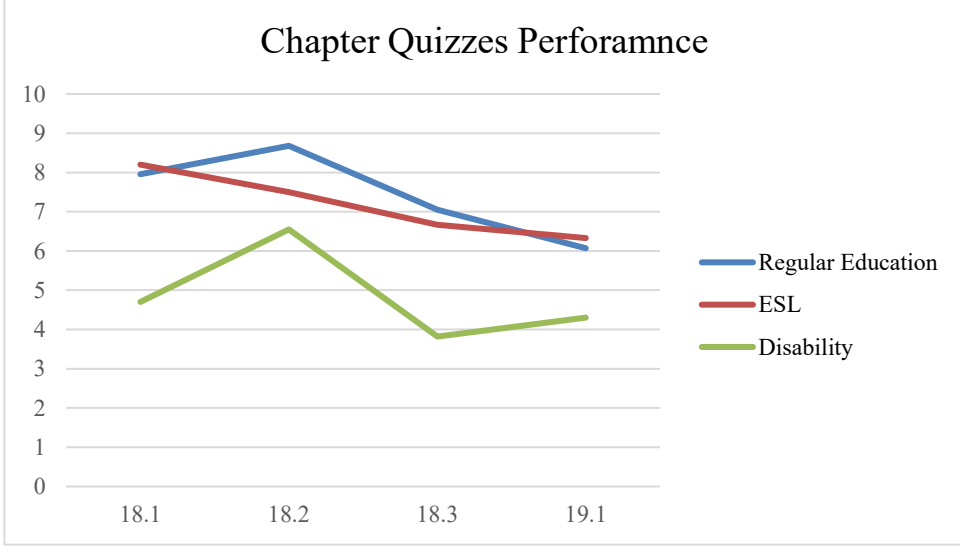

Figure 3: Comparison of Groups' Performance on Chapter Quizzes

Discussion

The purpose of this study was to examine the impact of digital textbooks versus traditional textbooks on reading comprehension performance and applications of sixth grade students in a science inclusive curriculum. Based on four parts of the Ecology unit, which was identified from the Life Science curriculum, we developed four lessons that were impeded into the digital textbook. We developed and administrated four pre- and post-quizzes to measure students' comprehension performance. We also developed two rubrics for two project-based curriculum

(Ecocolumn and Food Web) to measure students' applications of what they had learned. It should be noted that the researcher developed the materials in collaboration with the science and special education teachers.

We found that there was no statistically significant difference in comprehension performance between the control and treatment groups in both phases. Within the groups, however, the participants in both groups performed better in the post-quizzes compared to the pre-quizzes across the two phases. These results are similar to previous studies (e.g., Chulkov & VanAlstine, 2013; Daniel & Woody, 2013; Delgado et al., 2018) that found no difference in comprehension performance between students reading via digital textbooks versus the ones reading via traditional textbooks. Other studies (e.g., Mangen et al., 2013) further found students secondary reading from traditional textbooks outperformed students reading via digital textbooks.

We also determined that SWDs performed lower than students without disabilities in chapter quizzes. Svensson et al. (2021), for example, found no significant difference between the secondary SWDs reading via digital textbook versus the ones reading via traditional textbook. Unlike previous studies, this study went beyond examining only students' comprehension performance and studied students' application based on what they had studied. Th results further revealed that there was not statistically significant difference in applications (Ecocolumn and Food Web projects) between the control and treatment groups. However, the treatment group performed better than the control group in the Food Web project.

Limitations

Regardless of the slightly significant outcomes, this study had some limitations related to design, participants, and assessments. In our design, we implemented a control-treatment counterbalanced design (to ensure both groups have access to the digital textbook) using convenience sampling of six classes dividing them into two groups. In the 1st phase, group 1 was treatment group, and group 2 was the control one; in the 2nd phase, groups switched, so group 1 become the control group and group 2 become the treatment group. Each group was supposed to have three classes, but because there were two higher functioning classes, we kept these two classes as control groups in both phases. For that, control group included four classes in both phases because we believed structuring the groups in such way would decrease the results' bias and provide more reliable outcomes related to the intervention.

In regard to participants, as stated previously, there were two classes that included high functioning groups. A fair number of these students are gifted and performing higher the students in the rother four classes, respectfully. Since we implemented a convenience sampling, we did not have the control to randomize the participants, which negatively affected our method of sampling the participants. We assume that the intervention did reveal positive results because of the problems we encountered in sampling the groups. In other words, assigning the two high functioning classes to the control group in both phases might decrease the possibility of revealing statistically significant results of the intervention.

The third limitation was the lack of formal comprehension assessments. The measurement of this study was researcher-developed assessments. We created four pre and post multiple choice quizzes to measure students' comprehension performance and two rubrics to measure the applications of students' understanding of the science content. Measuring comprehension, as known, is a complex procedure and measuring such skill through paper-pencil quizzes is still not visible (Francis et al., 2005). We developed and used our researcher-developed multiple-

choice questions because a fair number of studies that administrated standardized reading comprehension measures did not reveal significant results due to the incompatibility between the standardized assessments and the intervention target (O'Reilly et al., 2014). Standardized reading comprehension measures also do not measure how students' reading and deriving methods of the content (Davis & Guthrie, 2015); further, traditional school-based reading comprehension assessments are not developed to measure the difference between students during comprehending a text (Carlson et al., 2014).

Even though multiple-choice questions are traditionally presented after an entire text, so they measure the product of comprehension rather than procedures of comprehension itself, they are still easier in administration, scoring, and less costly than open-ended questions (Carlson et al., 2014). Although open-ended questions enable the readers to demonstrate the procedures of comprehending a text, they need a lot of time to be scored and administrated (Carlson et al., 2014; Francis et al., 2005). Francis et al. (2005) stated that it is usually challenging to use comprehension questions that are easily readable and scored due to funding issues and number of students involved on the study. Given the aforementioned factors, we had to create our own quizzes in order to measure students' comprehension performance accurately.

Implications and Future Direction

Given the study's revealed results and limitations, we pose the following implications for policymakers, researchers, and practitioners. Before integrating digital textbooks into classrooms, teacher's role and training should be revisited (Dobler, 2015; Engbrecht, 2018). Policymakers may consider encouraging teacher education programs to create courses that equip preservice teachers with the theoretical knowledge and practical training that enable them to teach in inclusive settings. In addition, policymakers may encourage schools to provide inservice teachers with professional development opportunities (e.g., conferences, workshops) that enable them not only to teach in inclusive settings but also to help these students access content; simply, improving teachers practices should improve students' outcomes (e.g., reading comprehension).

In regard to research, future research should continue investigating the impact of digital textbooks on students' performance in inclusive settings. However, they may need to consider the following suggestions. While designing digital textbooks, they need to utilize applicable designing theories and theoretical frameworks, such as UDL and its guidelines, that can leverage the development of these digital textbooks. By doing so, researchers can develop and build sophisticated digital textbooks that enable students in inclusive settings to access content easily, which may enhance their educational outcomes. In this study, we included the science and special education teachers in the design of the digital textbook; however, we encourage future research not only include the teachers but also a technology developer who has expertise in designing such technology-based solutions.

Future research may consider investigating students and teachers' perceptions of digital textbooks while conducting the experimental intervention; this may provide researchers with more insightful results that explain the intervention-related outcomes, especially when it comes to students' performance. In addition, given digital textbooks are increasingly adopted in and outside classrooms, educators may need to investigate the issues related to utilizing such technology (Bouck et al., 2016; Mardis & Everhart; 2013). For example, some students may not have access to technology-based solutions in their homes, which may affect their ability and interest while reading via and interacting with content through digital textbooks. Considering such issues should provide teachers with comprehensive results, especially when it comes to

students' accessibility in inclusive settings.

In regard to practice, practitioners may consider the following aspects. Practitioners should implement technology-based solutions like digital textbooks with caution, especially when it comes to inclusive settings. It is critical for educators to select technologies that can practically be used and enable students to access content (Bouck et al., 2016). In order to do so, educators including special and general education teachers should train students on how to use any technology-based solution prior to utilizing it within their classrooms. Training students on such technologies does not only enable them to learn about such technologies but also using them efficiently to learn about the class content (e.g., science content). Educators, especially the ones in inclusive settings, need to consider learning how to utilize frameworks, such as UDL, in designing their lessons in order personalize the learning for each student; utilizing such framework does not help students learn and access content effectively but also meets their individual needs and goals and promotes their agency as learners.

Data Availability Statement

The raw data supporting the conclusions of this article will be made available by the author, without undue reservation.

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