Learning Disabilities: A Contemporary Journal 18(1), 3-25, 2020

Enhancing Science Vocabulary Knowledge of Students With Learning Disabilities Using Explicit Instruction and Multimedia

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Science includes a multitude of specialized terms that are not consistently taught using effective practices. Often, students with disabilities rely on ineffective strategies in order to memorize word definitions, which inhibits their science achievement. Using a counter-balanced design, we tested whether having access to multimedia videos that incorporate evidence-based practices would influence participating students' scores on vocabulary assessments. Additionally, we investigated whether the number of video views by students predicted assessment scores. Results from this study demonstrated positive science assessment outcomes when students have access to the multimedia videos. Overall, a greater number of video views predicted better student assessment outcomes. Implications for multimedia video use and future research are discussed.

Keywords: **Content Acquisition Podcasts, Science, Vocabulary, Learning Disabilities**

Introduction

Historically, students in the United States have underperformed on science achievement tests (National Assessment for Educational Progress (NAEP), 2018). Students with high-incidence disabilities, such as specific learning disabilities (LD), who have an individualized education plan (IEP) consistently score lower on science achievement measures than peers without an IEP in general education settings. For instance, 66% of eighth-grade students with disabilities earned scores indicating a "below basic" understanding of science compared to 28% of students without an IEP (NAEP, 2018). The underperformance of students with LD continues into high school, as many are unsuccessful in science courses, if they enroll in them at all (Gottfried & Sublett, 2018; Shifrer et al., 2013). As such, only 4.72% of students with LD pursue a science, technology, engineering, and mathematics (STEM) major in college (Wei et al., 2013), which in part leads to the underrepresentation of individuals with disabilities in STEM careers (National Science Foundation, 2015).

Although common characteristics of LD such as memory and information processing difficulties and struggles with aspects of reading (e.g., vocabulary knowl-

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edge) could contribute to underperformance in science, another cause is teachers not consistently providing evidence-based science vocabulary instruction (Bryant et al., 2017; Kaldenberg et al., 2015; Kennedy et al., 2017; Mason & Hedin, 2011). Student science-vocabulary growth is associated with whether they are explicitly taught the vocabulary terms (Carrier, 2013). In addition, secondary-content teachers are reportedly disinclined to explicitly teach vocabulary terms as they feel that (a) it is not their responsibility, as to do so takes away from content (Guthrie & Klauda, 2012), (b) they are unprepared to effectively teach vocabulary (Barry, 2002; Berne & Blachowicz, 2008; Thibodeau, 2008; Johnson & Massey, 2012), and (c) science should be taught solely through activities and inquiry-based learning (Fisher et al., 2009; Johnson & Massey, 2012). However, when students do not know key vocabulary terms and concepts, they will not be in a position to participate in scientific conversations and inquiry activities (Jackson, 2013; Parsons & Bryant, 2016).

Beyond the avoidance of and uncertainty about teaching vocabulary in the content areas, many science teachers are underprepared to effectively instruct SWD, as only one-third of educators reported receiving specific training in this domain (Kahn & Lewis, 2014; Villanueva et al., 2012). As students with an IEP spend 80% or more of their day in the general education classroom (National Center of Education Statistics, 2019), it is crucial to develop methods to support science teachers not only in working with this population, but also in providing evidence-based vocabulary instruction. Multimedia has shown promise in providing supplemental instruction to enhance vocabulary knowledge among students with high-incidence disabilities (e.g., Kennedy et al., 2014; 2015; Xin & Rieth, 2001). In this study, the use of a multimedia tool was investigated to determine its efficacy in supporting science vocabulary growth among middle-school students with high-incidence disabilities such as LD.

The Role of Vocabulary in Science Instruction

In order to succeed in state science assessments, students must demonstrate adept literacy abilities (Scruggs et al., 2013). One of the key science-specific literacy skills targeted by these measures is the ability to comprehend the meanings of keywords, phrases, and symbols and apply them towards understanding science content and concepts (Common Core State Standards Initiative, n.d., Scruggs et al., 2013; Virginia Department of Education (VDOE), 2018). For instance, the middle-school Next Generation Science Standard MS-ESS2-2 states that students should be able to "Construct an explanation based on evidence for how geoscience processes have changed Earth's surface at varying time and spatial scales" (NGSS, 2013). To do so would require a student to understand terms such as "plate motions," "microscopic," "catastrophic," "surface weathering," and "deposition." The meanings of these terms along with phrases found in the standard such as geoscience processes and spatial scales could be potentially elusive for students LD. In fact, science includes a large quantity of complex, specialized vocabulary words that, without instruction, could obstruct the understanding of students with LD (Kaldenberg et al., 2015; Mason & Hedin, 2011). Further complicating matters, some of the science terms hold alternative meanings in other content areas and in daily life (e.g., cell, fault, solution) which hinders comprehension (Fang, 2006; Rice & Deshler, 2018). Unfortunately, there is no magic set of practices that will remedy this significant and omnipresent issue.

Typically, very little instructional time is dedicated to teaching vocabulary terms outside of language arts (Scott et al., 2003). This can lead to students compensating by using strategies to memorize word meanings and facts; however, they often do not understand or allocate the time towards understanding the associated scientific concepts (Harmon et al., 2005; Songer & Linn, 1991). Additionally, many students with LD tend to lack memorization and reading strategies, which compromises their ability to acquire new vocabulary knowledge (Baker et al., 1995). Although some may believe that students could learn the meaning of vocabulary terms through reading instruction alone, Seifert and Espin (2012) found that it is necessary to include vocabulary-specific interventions to receive effective outcomes in the students' knowledge of terms. To address this, the use of technology has shown promise in supporting vocabulary knowledge growth in students with LD (e.g., Kennedy et al., 2014; 2015; Xin & Rieth, 2001).

Using Technology to Support Vocabulary

The use of technology (e.g., computer-assisted interventions, multimedia) to provide vocabulary instruction has been supported in the literature (Bryant et al., 2003, Jitendra et al., 2004; Kuder, 2017). However, there are limited published studies pertaining specifically to using technology to enhance science vocabulary knowledge – especially for students with disabilities. Despite the lack of guiding studies, the usage of images may enhance student recall of information which could further improve student science test performance (Cohen, 2012). To demonstrate, studies investigating the use of technology with secondary students and students with disabilities will be discussed.

Xin and Rieth (2001) sought to determine the effectiveness of video-anchored instruction in enhancing science vocabulary knowledge of students with LD. They conducted a pre- and post-test control group study in which they taught 76 fourth through sixth-grade students with LD vocabulary words related to earthquakes through the use of video or by reading passages. The researchers found that students who were taught using the videos significantly outperformed their peers who only had access to the reading passages. In addition, they determined that video-based instruction enhanced word meaning knowledge. However, the ability to generalize word meanings was not significantly different between students who had access to the videos and those who read the passages. Likewise, online graphic organizers (Reed et al., 2019) and computer-assisted interventions (Reinking & Rickman, 1990) have shown promise in supporting student science-vocabulary growth.

Koury (1996) conducted a study in which students with and without LD participated in discussions with or without video anchors (i.e., short video clips) to determine the impact on science-vocabulary knowledge. The 123 participating students were placed into one of the following groups: (a) students without disabilities who did not have access to the video anchors, (b) students without disabilities who had access to the video anchors, and (c) students with LD that used the video anchors. Koury found that students without disabilities performed better than students with LD on science vocabulary posttests. However, only posttest scores were analyzed. Without pretest data, it is impossible to determine the amount of growth the students had made. Likewise, the study did not include a control group consisting of students with LD that did not have access to the anchor videos. With these factors in mind, it is unclear how effective or ineffective the videos truly were for students with LD.

Researchers have also demonstrated the usefulness of technology to enhance the science vocabulary of students with disabilities (such as autism spectrum disorders (ASD) and intellectual disabilities (ID). McMahon and colleagues (2016) conducted a multiple probe across behaviors design study in which participating postsecondary students (one with autism spectrum disorder (ASD) and three with intellectual disabilities (ID)) used 25 to 30-second-long augmented reality videos to learn science vocabulary words (e.g., organs, bones). The focus was to determine whether students would identify and label the science terms accurately after receiving an augmented reality intervention. The videos included a slide with the vocabulary word, a video of the definition being read aloud, an image used in a labeling activity of the term, and a three-dimension simulation showing the location of the object described by the vocabulary term. Participants scanned vocabulary cards using a tablet to initiate the augmented reality intervention. Researchers found that all of the students improved in defining and labeling vocabulary terms with each use of the augmented reality vocabulary instruction.

Likewise, McKissick and colleagues (2018) conducted a study in which three middle- school students participated in a single-case multiple probe across participants design study to determine whether the use of computer-assisted intervention (CAI) enhanced student identification of science vocabulary terms as related to amoebas. The intervention consisted of 12 to 17-minute-long slideshows that included model-test explicit instruction and videos. The sequence followed an introductory video to provide context for the science terms, a video to explain the function of the vocabulary words (e.g., cell membrane), then identifying on an image of an amoeba where the targeted term is located. They found that the use of slideshow videos was an effective way to support science-vocabulary-identification growth among middle-school students with ASD and ID. This study built upon the work of Smith and colleagues (2013), which determined that the use of slideshows that utilized explicit instruction within a model/ test intervention format improved science-term recognition and identification among middle-school students with ASD and ID.

To investigate whether the use of a hypermedia learning environment (i.e., components beyond text such as links, graphics, sound, and video elements) can support student science academic-vocabulary development, Pritchard and O'Hara (2009) conducted a mixed-methods study involving 14 middle-school, English Learner (EL) students. In this study, participating students created science reports about vertebrates and invertebrates using hypermedia. The project was completed in three phases. Phase 1 consisted of activities to support student connection building between the known target words and the science concepts they portray through visuals and audio. At phase 2, students worked with partners to perform a web search to learn the meaning of unfamiliar terms. When students reached phase 3, they used what they learned about the terms and applied the strategies learned in phase 1 (e.g., using images and hypermedia to support word learning) to enhance understanding of the new term meanings. Student learning was measured using their responses about what the science terms meant. The authors reported that student understanding of words increased over time, and the students used the words appropriately within their hypermedia reports. In other words, the participants could represent the meaning of the term using text and visuals and could provide an explanation of what the word meant.

This brief section reviewed the few empirical studies where vocabulary performance of students with disabilities and English Learners in science courses was explored. It is clear that more research is needed and that research should be accompanied by innovation to bring new ideas to the hands of scholars, practitioners, and students. The purpose of this paper is to introduce an innovation in this space, and report results from a pilot test of impact on student learning.

Content Acquisition Podcasts. Content Acquisition Podcasts (CAPs) are short, multimedia vignettes that are created to reflect Mayer's cognitive theory of multimedia learning (CTML; 2009) and associated instructional design principles (2008). The CTML is grounded in cognitive load theory (Chandler & Sweller, 1991), the dual processing principle (Paivio, 1986), and Baddeley's (1986) construct of working memory with an active executive processor that facilitates communication between active and long-term memory. In practice, each CAP uses vivid images, clear narration, and limited on-screen text to provide the learner with exactly the information they need to spur active learning, and not overwhelm limited cognitive resources (Kennedy, Wagner, et al., 2016). CAPs can be used for a range of purposes. For example, CAPs are designated by their intended audience; such as CAPs for Teachers (CAP-T) or students (CAP-S). This study involves CAP-S.

Each CAP-S contains a prescribed instructional sequence of select elements of explicit instruction as recommended by Archer and Hughes (2011). The sequence is: introduction and rationale for video, name the term, review critical background knowledge, provide student-friendly definition, provide example, provide non-example (if clear non-example exists, otherwise skip), highlight morphological features of word (if clear elements exist, otherwise skip), repeat definition. The CAP contains explicit visual and auditory cues for each element. Here is a sample CAP: http://qmediaplayer.com/show.htm?1000.

Kennedy and colleagues have done multiple studies focusing on the use of content acquisition podcasts for teachers (CAP-T) to support the learning of pre- and in-service teachers (e.g., Ely et al., 2014ab, 2015; Kennedy et al., 2016a, b, 2017, 2018) as well as secondary students (Kennedy et al., 2014, 2015). Findings from these studies support the use of CAP-T to enhance preservice teacher knowledge of (a) how to give a functional behavioral assessment (Kennedy et al., 2016a; Hirsch et al., 2015), (b) the use and application of curriculum-based measures (Kennedy et al., 2016b), (c) early reading instructional skills (Driver et al., 2014; Sayeski et al., 2012), and (d) vocabulary instruction (Alves et al., 2018; Ely et al., 2014ab). Additionally, Kennedy and colleagues found that the use of content acquisition podcasts for teachers with embedded videos (CAP-TV) supported preservice teachers in learning evidence-based practices for vocabulary instruction (Peeples et al., 2019) and writing strategy instruction (Romig et al., 2018). For in-service teachers, the use of CAP-TV supports teacher learning of vocabulary instruction (Ely et al., 2015) and behavior management practices (Kennedy et al., 2017a). In addition, Kennedy and colleagues (2017b, 2018) also found that the use of CAP-TV as part of a professional development experience can support in-service middle-school science teachers in providing high-quality science vocabulary instruction. While this gives an indication that the use of a CAP-based tool may support science vocabulary learning, Kennedy and colleagues' (2017b, 2018) studies focused on the learning by middle-school science teachers.

Prior research on CAPs for students. In order to determine whether using CAP-S that included evidence-based vocabulary practices and CTML principles would improve vocabulary knowledge of tenth-grade social-studies students with and without LD, Kennedy and colleagues (2014) conducted a quasi-experimental study in which students used CAP-S or text-only definitions to learn vocabulary terms in social studies. They found that students with LD learned the information quicker when using the CAP-S and were able to close the gap with their peers without disabilities who did not have access to the CAP-S. Likewise, in Kennedy and colleagues' (2015) study, they found that when high-school students with and without LD used CAP-S, they were more successful in learning the social studies vocabulary terms than their peers who used versions of the videos that did not follow CTML. Both of these studies had small sample sizes and caution should be taken in extending the results to the general population; however, these findings indicate that CAP-S have promised to be effective intervention tools to enhance student content vocabulary knowledge. Because these studies occurred in social studies courses, is unknown whether they will provide students with LD and other high-incidence disabilities with supplemental instruction that will result in learning gains in science.

Purpose & Research Questions

Although these two studies show promise for the use of CAP-S for students with high-incidence disabilities, the content taught was social studies, and the participants were in high school. It is unknown the extent to which younger students will respond to the use of CAP-S for learning vocabulary terms and concepts within science. In addition, in prior CAP studies, no effort was made to expose students to the terms multiple times in a naturalistic way that might better mimic how students use supplemental learning materials. The impact of watching a CAP video multiple times will likely have an impact on student learning, but the precise amount is currently unknown.

As noted above, inclusive science teachers are not known for their quality of or quantity of vocabulary instruction. Therefore, by providing students with disabilities access to CAP-S which provide high-quality vocabulary instruction as a supplemental resource to whatever methods are already in place, it is possible that improvement in this area may be possible. Our key question in this project is to tackle the first question as to the extent to which CAP-S are useful for boosting student vocabulary learning. Specifically, the questions being investigated in this study include:

1. To what extent does having access to CAP videos during a unit impact the posttest scores of students with LD compared to peers who did not have access?
2. To what extent does the number of views of a CAP help explain vocabulary scores of students with LD on dependent measures of vocabulary performance?

Method

Setting and Participants

The University Human Subjects Committee, the participating school district's research review board, the principal of the school, teachers, the parents of all students, and the students gave permission to conduct this research. The school district is located in a rural, Mid-Atlantic county of about 41,000 residents. The middle school (sixth through eighth grade) that participated had approximately 550 students the year of the study. The researchers recruited two seventh-grade teachers and their students to participate. A total of 43 students with an IEP for a high-incidence disability (e.g., LD, ADHD/OHI, EBD, Speech/Language Impairment) received parental permission to participate. Of the participants, 17 (39.5%) were female, and 26 (60.5%) were male. Caucasian students represented the largest ethnic subgroup ($N = 25$, 58.1%), Hispanic/Latinx students were the next largest group ($N = 17$, 39.5%), and an African-American student comprised the balance ($N = 1$, 2.3%). Students with LD were the largest group (n = 30), followed by ADHD (n = 8), SLI (n = 4), and EBD (n = 1). The students were split among the two teachers by a count of 23 in Teacher 1's sections, and 20 in Teacher 2's sections.

The mean age of participants was 12.5 years. Permission to collect individual socioeconomic status could not be obtained from the school district's human subjects review board. However, given that 76% of the students in the school received free or reduced-price lunches, we assume an approximately matching percentage of participants were from this socioeconomic group. Approximately 200 students were enrolled in the seventh grade during the year of the study; the 43 students with an IEP constituted 21.5% of the total number of students in the grade. Specific reasons for the elevated percentage of students with IEPs compared to state and national averages are unknown. The researchers speculate that a combination of factors including the economically depressed region where the study was conducted, limited school resources, and education/health of parents were involved. The percentage of students with an IEP in the school was 19%.

Teacher participants. Two certified seventh- grade science teachers from the same school participated in this study. Teacher 1 was a Caucasian female with a master's degree in her seventh year of teaching. Teacher 2 was a Caucasian female with a bachelor's degree in her third year of teaching. Both teachers received an honorarium from a fund for pilot research established at the first author's university. The teachers each taught five classes of science throughout the day, lasting approximately 50 minutes each. Students with disabilities were included with peers without IEPs in select sections. According to the two teachers, the district was unable to staff sections with students with IEPs with a dedicated special education co-teacher. Special educator support was available, but those professionals were working in numerous classrooms and had other unspecified duties. They, therefore, did not play a role in this study. Students without IEPs were not included in this study given the research team's focus on the impact of CAPs on learning for students with high-incidence disabilities. The teachers were located several hours from the researcher's university, so regular observations of their teaching were not possible. Instead, the teachers each recorded themselves teaching a lesson at baseline to show researchers what vocabulary instruction in science might look like on a typical day. Results of the sample lessons are noted below.

Procedures

Intervention. This study is a pilot of CAP-S for supporting vocabulary development among students with high-incidence disabilities in middle-school science. Each CAP is intended to help students figure out the meaning of unknown words using elements of explicit instruction delivered within a multimedia package. CAP-S can be used by students working alone, or a teacher can integrate videos into an explicit lesson. In this study, teachers used the CAP-S in both ways. Each CAP was shown once during the intervention week to ensure student exposure. Then, students had access to the library of videos through a free website called Ed Puzzle (www.edpuzzle.com). Ed Puzzle allows instructors to create a "course" where students log in with individual credentials and access content. Ed Puzzle tracks the number of times each student watched each video and provides a mechanism to embed questions on top of videos created in outside platforms. Teachers encouraged students to watch each video as many times as they deemed necessary to learn and feel comfortable with the term. Teachers provided cues to students to watch videos as a study aid and to help with mastery, but they took no disciplinary or other action if students did not comply. Teachers were directed by researchers to use CAP-S during class and on www.EdPuzzle.com along with any typical approaches for vocabulary they had planned. Students watched CAP-S during independent time in class, during study hall periods, at home, and at any other time when connected to the Internet.

CAP-S were created by members of the research team using PowerPoint. Slides were created in accordance with Mayer's instructional design principles (2008) using a prescribed sequence of elements of explicit instruction noted in the preceding section of the manuscript. Researchers used a fidelity checklist for Mayer's principles (see Weiss, Evmenova, Kennedy, & Duke, 2016) and for inclusion of key explicit instruction elements (see Kennedy, Deshler, & Lloyd, 2015) to ensure each CAP met quality standards. The senior author on the paper oversaw construction of the CAP-S, and signed off on their adherence to technical and content standards. A local inclusive science teacher who was not part of the project also reviewed each CAP-S to ensure the science content was correct and appropriate for the seventh- grade audience.

Selection of terms. The intervention lasted for ten weeks and spanned four units. Prior to implementation, researchers worked with the teachers to identify vocabulary terms they planned to teach in the forthcoming units. A total of 56 words were identified using this procedure (14 from each unit).

It was not possible to randomly assign students to experimental conditions. Therefore, the two teachers used a counter-balanced design by alternating units either using CAP-S or using their regular approach to vocabulary instruction within science. In week one, the teachers drew straws to see which one would have students access CAP-S first and which would begin using a business-as-usual (BAU) approach. Teacher 1 drew the long straw and had students use the videos during the unit as a supplement to their regular teaching. Teacher 2 taught the same words using a BAU approach (no CAP-S access). In week two, the teachers switched. Teacher 1 taught words 15-28 using a typical approach, and Teacher 2 had students use CAP-S. The alternating continued such that students had access to videos for two units and did not for two units. This permitted an opportunity to evaluate not only the performance among students in the two teachers' courses compared to one another but also to compare how students performed versus themselves on a unit to unit basis.

Measures

Researcher-created vocabulary measures. Researchers were interested in the extent to which middle-school students with high-incidence disabilities using CAP-S as a supplemental resource to learn science vocabulary terms would improve performance on measures of knowledge. The assessment had two parts: multiple-choice and open-ended. The multiple-choice measure was simple: For each term, the stem was "What is ____?" and then four answer choices were provided. This assessment was scored "0" for a wrong answer or "1" for a correct response.

The second, open-ended assessment asked the students to "Write what you know about the term including the definition, an example, and any other information you know." Each item was scored on a 0-4 scale. Students received two points for the correct definition, one point for a correct example, and another point if an additional piece of correct information was provided. It was possible to earn one point for a partially correct definition. Students completed the open-ended measure first and turned it in so as to not have access to potential answers from the multiple-choice measure. Teachers removed student names from the two parts of the assessment and replaced them with anonymous codes and then mailed the forms to researchers for scoring. The reliability coefficient for the multiple-choice measure was .91, and the coefficient for the open-ended measure was .85. Researchers double-scored the open-ended items to ensure consistency of scoring; 100% agreement was reached through discussion. Students with IEPs received their normal accommodations during these assessments, but in no instance was the assessment modified beyond what is noted above.

Number of student CAP views. Researchers were curious about the impact of naturalistic CAP views on student performance on the researcher-created measures. In a previous study of naturalistic CAP-T views in a teacher preparation course, future teachers' performance on various measures of knowledge increased as they viewed CAP-T more times during the semester (see Kennedy, Alves, et al., 2016). This finding was not surprising; however, expecting an automatic replication with students with LD in inclusive middle-school science courses is not a foregone conclusion. For one, it was unknown if students with LD would be motivated enough to watch CAP-S on their own without specific prompting. In addition, knowing which CAP-S received more views could potentially teach interesting and valuable lessons about which terms students found most challenging, and statistical analyses can reveal if more views resulted in stronger performance on the various assessments. In this study, students accessed CAPs with individual logins through Ed Puzzle (www.edpuzzle.com), which tracked their number of views per video.

Teacher baseline video. The two teachers recorded themselves teaching a lesson where vocabulary instruction occurred and mailed the video to researchers. Researchers used a prior version of the Classroom Teaching (CT) Scan to code the videos (Kennedy, Rodgers, et al., 2017). The CT Scan is a low-inference observation tool that allows an observer to document each discrete instructional move of the teacher in real time (Kennedy, Rodgers, et al., 2018). The current version of the CT Scan is available at www.thectscan.com, and this video introduces the tool and how it works: https://vimeo.com/349115687. The CT Scan produces colorful data that allows the teacher and observer to see a data-driven timeline-formatted representation of the lesson. Here is a sample: http://classroomteachingscan.com/ctscan/timeline.htm?menus.txt&393.

Teacher 1 sent a video lasting 37 minutes. Of the 37 minutes, Teacher 1 spent approximately 16 minutes, 30 seconds teaching vocabulary. Within the 16:30, teachers provided a student-friendly definition (5:30) for two terms and asked students to orally apply knowledge of the terms with a series of questions (11:00). The remainder of the lesson was spent giving directions and monitoring student independent work. The teacher provided students with eight opportunities to respond (OTRs) during the vocabulary time. The OTRs included seven rote questions (what is photosynthesis?) and one deep question (why is photosynthesis so critical to life on Earth?). The instruction did not use any visuals; the teacher lectured as students took notes.

Teacher 2's video was 43 minutes long. Of the 43 minutes, only eight were spent on vocabulary instruction. The teacher provided formal definitions for three terms using PowerPoint slides with text only. Students copied the definitions into their notes. The remainder of the time the teacher had students work in groups to create a foldable study guide for an upcoming quiz. There were no specific OTRs provided during vocabulary time. Researchers have no way of knowing what vocabulary instruction looked like during the four units of the study. We can hypothesize instruction throughout the study mirrored the lesson that was watched, given their willingness to film it and send for review, but there really is no way to know for sure. Therefore, any speculation to that effect will not be included in this paper's conclusions.

Design

Because of the teachers' intact classes, it was not possible to randomly assign students to conditions or use a traditional between-groups design. Therefore, we counter-balanced each of the four units so students in sections of one teacher were using CAP-S for the unit while students in the other teacher's classes were not. The initial order of who used the videos first was random, but the teachers simply alternated back and forth in the following weeks. Each student had the opportunity to learn 56 total terms (14 terms each week); 28 using CAP-S, 28 in the BAU condition. Researchers used a series of ANOVAs and regressions to evaluate differences among and between groups.

Results

Students with disabilities in the two teachers' inclusive middle-school science classrooms completed two assessments following each of the four units. The assessments included 1) a multiple-choice assessment (e.g., what is photosynthesis?) and 2) an open-ended assessment (e.g., write the definition of photosynthesis, an example, and any other relevant information you may know). A pretest for the multiple-choice and open-ended assessment was given prior to each unit and a posttest was given after completion of the unit. Students with disabilities in Teacher 1's classes were given access to CAP-S as a supplemental learning tool during units 1 and 3. Peers from Teacher 2's classes were given access to the CAPs in units 2 and 4. Students had no way to access CAP videos during their off weeks. In the following, we report results from these assessments. This information is also presented in Table 1.

Table 1. ***Descriptive Data and ANOVA Statistical Analyses Comparing Students With CAP-S vs. BAU Assessment Scores***

	Descriptive Data						ANOVA		
	CAP			BAU					
Unit 1	***n***	**M**	**SD**	***n***	**M**	**SD**	**F**	**MS**	***d***
MC Pre	23	2.96	2.16	20	2.20	1.94	1.44	6.12	
MC Post		12.26	2.60		10.10	4.15	4.30 *	49.95	0.62
OR Pre		2.17	2.19		1.00	1.17	4.60 *	14.74	
OR Post		32.52	13.41		15.05	10.47	22.17 ***	3265.59	1.45
Unit 2									
MC Pre	20	4.10	1.83	23	4.96	2.75	1.39	7.85	
MC Post		13.20	2.09		9.87	3.60	13.16 **	118.66	1.13
OR Pre		2.30	1.78		2.96	2.34	1.04	4.61	
OR Post		33.05	10.87		19.65	13.93	12.08 **	1920.25	1.07
Unit 3									
MC Pre	23	5.61	3.59	20	5.75	2.61	0.02	0.21	
MC Post		14.22	1.73		12.65	3.95	2.97	26.28	0.51
OR Pre		5.78	4.10		4.25	4.23	1.45	25.13	
OR Post		48.48	11.09		28.40	14.24	26.94 ***	4312.62	1.57
Unit 4									
MC Pre	20	3.45	2.39	23	4.30	2.65	1.21	7.81	
MC Post		13.00	2.27		10.70	3.84	5.51 *	56.81	0.73
OR Pre		3.11	2.56		3.00	2.95	0.015	0.115	
OR Post		37.55	11.01		22.61	15.60	12.79 **	2388.18	1.11

Note. * = $p < .05$, ** = $p < .01$, *** = $p < .001$. MC Pre = Multiple-choice pretest; MC Post = Multiple-choice posttest; OR Pre = Open-response pretest; OR Post = Open-response posttest. MS = Mean Square between groups

Results for Unit 1 Assessments

Multiple-Choice Results. For units 1 and 3, the students with disabilities from Teacher 1's classes ($N = 23$) had access to CAP-S as a supplemental resource and completed a 14-item multiple-choice assessment as a pre- and post-test. The science teacher also reported teaching the terms using her normal approach during face-to-face class time. Students with disabilities from Teacher 2's classes ($N = 20$) did not have access to CAP-S videos but were taught the same terms by way of their teachers' business-as-usual approach. The pretest score for the unit 1 multiple-choice assessment for Teacher 1's students had a mean score of 2.96 out of 14 (SD = 2.20). Compared to Teacher 2's students' mean score (M= 2.20, SD = 1.94), there was no statistically significant difference between the classes ($F(1,41) = 1.44$. $p= 0.24$). At posttest, students who used the CAP-S for unit 1 had a reported mean score of 12.26 out of 14 (SD= 2.60), while students who did not have access to the CAP-S had a mean score of 10.10 (SD= 4.15). A statistically significant difference was found between students who did and did not have access to the CAP-S on their multiple-choice posttest scores ($F(1,41) = 4.30$, $p = 0.04$, d = 0.62).

Open-Response Results. For unit 1, the students with disabilities in Teacher 1 and 2's sections of seventh-grade science also took an open-ended vocabulary assessment. The open-ended assessment was given before the multiple-choice measure to prevent students from copying definitions from one another. Students could score between 0-4 points for each of 14 terms by providing correct information in writing about the term (e.g., definition, example, other relevant information) for a total possible score of 56. Student scores across the 14 terms at pre- and post-test were summed for these analyses. In terms of the open-response assessment, a statistically significant difference was found between the students who had access to the CAP-S and those who did not ($F(1,41) = 4.60$, $p= 0.038$). However, both groups started with relatively small mean scores. Specifically, the students who had access to the CAP-S had a mean score of 2.17 out of 56 (SD = 2.19), whereas students without access had a mean score of 1.00 (SD = 1.17). With that being said, while the results may be statistically significant, there is no educationally significant difference. At posttest, students in Teacher 1's classes earned a mean score of 32.52 out of 56 (SD = 13.41), while students in Teacher 2's classes earned an average score of 15.05 (SD = 10.47). There was a statistically significant difference between class scores $F(1,41) = 22.17$, $p< 0.001$, d = 1.45).

Results for Unit 2 Assessments

Multiple-Choice Assessment Results. For unit 2, students in Teacher 2's classes ($N = 20$) had access to the supplemental CAP resources whereas students in Teacher 1's classes ($N = 23$) did not. At pretest, Teacher 2's students had a mean score of 4.96 (SD = 2.75) compared to Teacher 1's students whose mean score was 4.10 (SD = 1.83). Differences in pretest scores between students in the two classes were not statistically significant ($F(1.41) = 1.39$, $p = 0.244$). However, at posttest for the multiple-choice assessment, students who had access to the CAP resource earned a mean score of 13.20 (SD = 2.09), while their peers who did not watch the CAP-S had a mean score of 9.87 (SD = 3.60). The difference between these groups was statistically significant ($F(1,41) = 13.16$, $p = 0.001$, d = 1.13).

Open-Response Assessment Results. Students who had access to the CAP-S scored on average a 2.30 (SD = 1.78) on the open-response pretest, while those who did not have access to the CAP-S earned a score of 2.96 (SD = 2.34) on the pretest. The difference between the two groups of students was not statistically significant ($F(1,41) = 1.04$, $p = 0.313$). However, a significant difference did appear in the open-response posttest scores between students who did and did not have access to the

CAP-S resources ($F(1,41) = 12.08$, $p = 0.001$, d = 1.07). Specifically, students who had access to the CAP-S earned on average a score of 33.05 (SD = 10.87) whereas students without access to the CAP-S earned a mean score of 19.65 (SD = 13.93).

Results for Unit 3

Multiple-Choice Assessment Results. As this is a counter-balanced design study, Teacher 1's students ($N = 23$) had access to the CAP-S resources again while students in Teacher 2's classes ($N = 20$) did not. The students in Teacher 1's classroom earned an average multiple-choice assessment score was 5.61 (SD = 3.59). Teacher 2's students had a mean score of 5.75 (SD = 2.61). The difference between the multiple-choice scores of these two student groups was not statistically significant ($F(1,41) = 0.02$, $p = 0.885$). The mean posttest score for students in Teacher 1's classes on the multiple-choice assessment was 14.22 (SD = 1.73). Students in Teacher 2's classroom earned an average posttest score of 12.65 (SD = 3.95). The difference in posttest scores was not statistically significant between the two groups of student participants ($F(1,41) = 2.97$, $p = 0.092$, d = 0.51).

Open-Response Assessments Results. On average, students in Teacher 1's classes earned 5.78 points (SD = 4.10) on the open-response pretest. Students in Teacher 2's classes had a mean score of 4.25 (SD = 4.23) on the open-response pretest. The difference in scores between students in the two teachers' classes was not statistically significant ($F(1,41) = 1.45$, $p = 0.235$). However, the difference in open-response posttest scores between the two classes was statistically significant ($F(1,41) = 26.94$, $p < 0.001$, d = 1.57). In particular, students in Teacher 1's classes earned an average score of 48.48 (SD = 11.09) whereas Teacher 2's students had a mean score of 28.40 (SD = 14.24).

Results for Unit 4

Multiple-Choice Assessment Results. For unit 4, students in Teacher 2's classes had access to the CAP-S resources, while students in Teacher 1's classes did not. On the multiple-choice pretest assessment, students from Teacher 2's classes had a mean score of 3.45 (SD = 2.39), and students from Teacher 1's classes earned an average score of 4.30 (SD = 2.65). The difference in scores between the students in these classrooms was not statistically significant ($F(1,41) = 1.21$, $p = 0.277$). The students from Teacher 2's classes earned an average score of 13.00 (SD = 2.27) on the multiple-choice posttest whereas Teacher 1's students had a mean score of 10.70 (SD = 3.84). The difference in posttest scores between the teachers' classes was statistically significant ($F(1,41) = 5.51$, $p = 0.024$, d = 0.73).

Open-Response Assessment Results. Students in Teacher 2's classes earned a mean score of 3.11 (SD = 2.56) on the open-response pretest compared to an average score of 3.00 (SD = 2.95) earned by Teacher 1's students. The difference in pretest scores between these two classes was not statistically significant ($F(1,41) = 0.015$, $p = 0.904$). However, at posttest, the differences in scores between students who did or did not have access to the CAP-S was statistically significant ($F(1,41) = 12.79$, $p = 0.001$, d = 1.11). Specifically, students from Teacher 2's classes earned an average score of 37.55 (SD = 11.01) on the open-response posttest, while students from Teacher 1's class had a mean score of 22.61 (SD = 15.60).

CAP-S Views and Their Association with Student Posttest Scores

To determine what influence the number of CAP-S views has on the multiple-choice and open-ended response posttest scores, regression analyses were conducted. Students watched CAP-S within the website Ed Puzzle, which provided researchers with a number of views for each video to use in analyses. Through regression, it is possible to determine whether the number of views significantly predicts student posttest scores. In addition, the amount of variance and change in standard deviations in student scores that can be attributed to CAP views can be found. As mentioned prior, Teacher 1's students had access to the CAP-S for units 1 and 3, while the students from Teacher 2's classes had access to the CAP-S for units 2 and 4.

The twenty-three students from Teacher 1's classes viewed the CAP-S for unit 1. On average, students viewed the CAP-S 36.43 times (SD = 9.23) with a range of viewership between 21 and 53 times. The association between the students' total number of CAP-S views and their multiple-choice assessment scores was statistically significant ($\beta = 0.864$, $t(21) = 7.847$, $p < 0.001$, $R^2 = 0.746$). Specifically, a one-unit increase in student total CAP-S views is associated with a 0.864-unit increase in his/her multiple-choice posttest score. Likewise, the total number of student CAP-S views was significantly related to their open-response posttest scores ($\beta = 0.911$, $t(21) = 10.090$, $p < 0.001$, $R^2 = 0.829$). In other words, a one-unit increase in total CAP-S views was also associated with a 0.911-unit increase in the students' open-response posttest scores.

For unit 2, Teacher 2's students (N = 19) viewed the CAP-S. On average, the students viewed the CAP-S 35.47 times (SD = 5.76) with viewership ranging from 17 to 41 times. The association between the total number of student CAP-S views and their multiple-choice posttest scores was statistically significant ($\beta = 0.853$, $t(17) = 6.750$, $p < 0.001$, $R^2 = 0.728$). A one-unit increase in CAP-S views is associated with a 0.853-unit increase in student multiple-choice posttest scores. The total number of student CAP-S views was also significantly associated with their open-response posttest scores ($\beta = 0.886$, $t(17) = 7.893$, $p < 0.001$, $R^2 = 0.786$). Specifically, a one-unit increase in the total number of CAP-S views is related to a 0.886-unit increase of student open-response posttest scores.

During unit 3, Teacher 1's students (N = 23) again had the ability to view the CAP-S. The students viewed the CAP-S a total of 56.17 times on average (SD = 6.04) with a range of viewership between 44 and 65 times. The relationship between the number of CAP-S views and student multiple-choice posttest scores was statistically significant ($\beta = 0.705$, $t(21) = 4.561$, $p < 0.001$, $R^2 = 0.498$). A one-unit increase in total CAP-S views is related to a 0.705-unit increase in multiple-choice posttest scores. The association between the total number of student CAP-S views and their open-response posttest scores is statistically significant ($\beta = 0.841$, $t(21) = 7.109$, $p < 0.001$, $R^2 = 0.706$). A one-unit increase in student total CAP-S viewership is associated with a 0.841-unit increase in their open-response posttest scores.

Lastly, students in Teacher 2's classes (N = 20) viewed the CAP-S during unit 4. On average, the students watched the CAP-S 45.50 times (SD = 6.20). The relationship between the total number of student CAP-S views and their multiple-choice posttest scores were statistically significant ($\beta = 0.478$, $t(18) = 2.310$, $p = 0.033$, $R^2 = 0.229$). In particular, a one-unit increase in the total number of student CAP-S views is associated with a 0.478-unit increase in student multiple-choice posttest scores. The total number of student CAP-S views is also significantly related to their open-response posttest scores ($\beta = 0.629$, $t(18) = 3.435$, $p = 0.003$, $R^2 = 0.396$). A one-unit increase in students' total CAP-S views is associated with a 0.629-unit increase in their open-response posttest scores.

Discussion

Marzano and Pickering (2005) state that the "strongest action" teachers can take to provide students with the background knowledge necessary to access to content taught in school is teaching them content-specific words (i.e., academic vocabulary). Without it, academic success could be hindered as lacking an understanding of content-specific term meanings and may prevent students from engaging in conversations or knowing how to think about the topic appropriately (Nagy & Townsend, 2012). The science field includes a multitude of academic vocabulary terms that may inhibit achievement of students if they lack proper knowledge of word meanings (Rice & Deshler, 2018). The use of technology to support student vocabulary growth in science has shown promise, albeit with mixed results (e.g., Koury, 1996; Xin & Rieth, 2001). This study investigated the use of Content Acquisition Podcasts for Students (CAP-S) in supporting middle-school student science-vocabulary growth.

With the omnipresence of technology in our everyday lives, it is unsurprising that teachers often attempt to incorporate it in their classrooms. However, it is crucial that educators make sure that the tools they adopt into their instruction are actually effective. The use of technological tools to provide supplemental science-vocabulary instruction to SWD has been supported in multiple studies (e.g., McMahon et al., 2016; Reed et al., 2019; Terrazas-Arellanes et al., 2018). Results from this study add to this body of literature as the use of CAP-S as a supplemental learning tool shows promise in supporting middle-school students with disabilities in their science-vocabulary growth. This aligns well with findings from previous studies that support the use of CAP-S to develop content vocabulary knowledge among secondary-school students with and without disabilities (Kennedy et al., 2014; 2015) and expands to science.

Student CAP access and posttest scores. Overall, students who accessed CAP-S along with their typical instruction outperformed their peers who only had access to the regular teacher instruction. This suggests that when CAP-S are provided to students as a supplementary resource, they support student science-vocabulary learning. These findings were similar to those seen by Xin and Rieth (2001) in that students who had access to technology to learn word meanings outperformed their peers who did not. In addition, these results are similar to the findings from previous Kennedy and colleagues' studies in which the use of CAP-S enhanced the social-studies vocabulary knowledge of students with and without disabilities (Kennedy et al., 2014; 2015). Although comparisons of the scores between students who did and did not have access to the CAP-S yielded moderate to large effect sizes, the sample size in this study is relatively small. As such, the effect sizes should be interpreted with caution.

Associations between student CAP views and posttest scores. The total number of CAP-S views does influence scores on the multiple-choice and open-ended response measures, which suggests that with more CAP views, it is more likely to improve posttest performance. This supports previous research findings that multiple exposures to a word increases an individual's knowledge (Webb, 2007). In addition, Kennedy and colleagues' (2016c) study in which they found the total number of student-teachers' CAP views was significantly associated with their performance on their course exams. Specifically, more views of the CAP-S predicted better exam performance (Kennedy et al., 2016c). This study builds upon what Kennedy and colleagues found by showing that more views of the CAP-S also improved assessment performance among middle-school students in science.

Implications

As the majority of science general-education teachers report lacking training, time, and resources to provide effective instruction to students with disabilities (Kahn & Lewis, 2014), the use of CAP-S could provide support to these educators' efforts and enhance their students' science achievement. Having access to resources for implementing evidence-based instruction that can fit seamlessly into established routines is likely to promote the use of these practices by teachers (Torff & Byrnes, 2010). The CAP videos can meet this expectation as they are premade and require little extra time and resources from the teacher in order to use them. With this in mind, the use of CAPs could support increased use of evidence-based, explicit vocabulary instruction in the classroom which ultimately could result in positive student outcomes.

Content Acquisition Podcasts could be used to help build student background knowledge on terms so that they could engage with classroom activities in more meaningful ways. Having background knowledge of what science terms mean allows for students to build upon this information to make connections with the science concepts being taught. Although SWD traditionally utilize ineffective practices to learn science word meanings, CAP-S provides them with an alternative that could potentially decrease the achievement gap between them and their general-education peers.

The inclusion of CAP-S as a supplemental instructional tool within the science classroom could help support teachers in providing an inclusive environment for all students. As students come in with a diverse set of knowledge and familiarity with terms, inclusion of CAP-S may support an equitable footing in participating and completing inquiry-based investigations within the general-education classroom. The tool may be used to provide differentiated instruction by enhancing student exposure to the targeted science concepts in a scaffolded, explicit way. As some students may benefit from this multi-modal tool that displays the information orally, visually, and through providing opportunities for the students to respond, this approach may reach more students than relying on passive learning experiences or textbook definitions alone.

Future Research

In future studies, comparing the science-vocabulary growth of students without disabilities with SWD could provide insight as to whether the use of CAP-S and the number of CAP views could reduce the achievement gap. Additionally, increasing the sample size could increase the ability to generalize the results.

It is theorized that by following the tenets of CTML, the cognitive demands on the learner would decrease, allowing him/her to better retain the information in long-term memory (Mayer, 2009). In this study, participant's perceived cognitive load was not explicitly analyzed. In future studies, including the students' perceived cognitive demands would provide additional information as to why watching some CAP-S were associated with significant increases in participant posttest scores while others were not. If a word is perceived as being difficult to learn, it is possible that students would not score as well on questions related to that term regardless of their access to the CAP videos. Similarly, if students feel a term is "easy" and are confident in knowing its definition, students may score highly on questions related to that word regardless of their CAP access.

It is unknown how the terms fit into the teachers' overall lesson plans. It is important for students not only to learn the vocabulary terms but also to build their conceptual understanding of the content, which could be done with the incorporation of a related activity (Smith et al., 2013). Not only do student with disabilities have the ability to effectively engage in activity-based learning, but also researchers have found that the students often report more science enjoyment and improved achievement on science posttest measures (Lynch et al., 2007; Mastropieri et al., 1999; 2006). However, SWD are not likely to be successful in activity-based learning experiences if they are expected to construct the big ideas and concepts without any support (Mastropieri et al., 1997; McGinnis & Kahn, 2014). Researchers advocate for the integration of explicit instruction and inquiry-based learning in the science classroom (Therrien et al., 2011; 2017). The pairing of CAP-S, which provides explicit instruction, with an activity could lead to better science achievement results while also improving student experiences and views of the content. Future studies should investigate whether the use of CAP-S with an activity could further enhance student science achievement on vocabulary and content-based measures.

Limitations

Although the results of this study are promising, there are a number of limitations to be discussed. First, the sample size was small, which inhibits generalization to the broader population of students with disabilities. Similarly, the length of the intervention was limited to four total units of science with students receiving the intervention for half of that time. Second, researchers were unable to observe the business-as-usual science instruction for either teacher beyond one baseline video provided to the team. Although the baseline video was intended to be a representative sampling of their teaching, it is ultimately insufficient to determine the extent to which instruction was similar in quality or quantity within each classroom, and the teachers clearly had an unmeasured impact on the observed results. All measures were either researcher- or teacher-created, which inflated effect sizes and were closely linked to the independent variable. There were additional, uncontrolled variables that may have contributed to the results of this study that were not included (e.g., student motivation, teaching practices, use of time to teach vocabulary instruction).

Conclusion

The Next Generation Science Standards (NGSS, 2013) call for students to develop skills such as making an argument using evidence, analyzing and interpreting data, and communicating information effectively. Although results from this study indicate that CAP-S provide support in building student science vocabulary and content knowledge, it is unknown whether students can apply this information towards effective use of the NGSS practices in activity-based learning. Future studies should continue to investigate how CAP-S can contribute towards SWD meeting these goals. In addition, as state-science assessments require students to know the meaning of science terms and use their knowledge towards understanding the key-scientific concepts (CCSSI, n.d.; Scruggs et al., 2013; VDOE, 2018), it is necessary for teachers to include effective vocabulary-specific interventions in their practice to help their students meet this goal (Seifert & Espin, 2012). Educators are encouraged to consider using CAP-S as a supplement to their usual science-vocabulary instructional practices in order to promote positive outcomes for students with disabilities educated in the general-education science classroom.

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