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Abdelnaby, H., Romine, W. L., van Garderen, D., Milarsky, T., Agarwal, A., Lei, Q., Smith, C., Lannin, A., Folk, W., & Juergensen, R. (2023). Linking Science and Literacy Through Multimodal Text Sets: Student Perspectives. *NARST 2023 Annual International Conference*.
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Linking Science and Literacy Through Multimodal Text Sets: Student Perspectives

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Abstract

We present findings of a mixed methods study examining the perceptions of students' (with and without disabilities) understanding and engagement with multimodal STEM text sets. Exit slip and survey data were used to identify areas for improvement in the development of the multimodal STEM text sets for middle school students. Data were collected from 434 middle school students, 86 of whom had a disability, from six teachers' classrooms in Spring 2021. Significant differences in perceptions of understanding of argumentation were reported between students with and without disabilities. However, ratings of the lessons and the quality of learning, as well as interest in the topic, were statistically similar. Topic modeling on the responses showed that all students expressed similar learning experiences and confusions whether or not they were students with disabilities. This supports prior work which suggests that multi-modal text sets are an effective way to motivate students with a wide range of interests and abilities to engage with scientific literacy practices.

Introduction

Reading informational texts has become an essential everyday life skill for individuals' professional and personal success in the 21st century for all students including those with disabilities (Pearson et.al, 2010). Understanding these texts incorporates multiple processes including “interpreting information, synthesizing personal understanding, and learning to make one’s own thinking visible to others” (Bricker et al., 2017, p. 261). To make reading grade level scientific texts attainable to diverse learners, our program is developing multimodal STEM text sets and teacher professional development. For our program, a multimodal STEM text set includes a coherent sequence of multimodal resources and activities that pertain to a specific line of inquiry. The concept of text is extended to include textual/multimodal sources such as graphs, charts, tables, mathematical equations, diagrams, figures, and audio, video, and other digital resources. The line of inquiry of the text set is determined by an anchor text – a rich, complex grade-level text that reflects the grade level science and literacy standards. Within the multimodal STEM text set, scaffolds—both instructional and content—that are based on learner needs are integrated to support in building knowledge of the content and to support comprehension of the content. The multimodal STEM text set can be organized as a series of learning cycles/lessons that are

implemented with intentionality based upon the learner's needs and capabilities (Romine et al., in press).

Professional Development Program: Context and Implementation

Our program, Linking Science and Literacy for All Learners, supports 6th-8th grade science, English Language Arts, and special education teachers as they develop and implement multimodal STEM text sets. The teachers participate in a year-long professional development program designed to acquaint them with multimodal STEM text sets and help their implementation. During the professional development, teachers are introduced to foundational ideas about multimodal STEM text sets with the focus on scaffolding instruction for diverse learners, including students with disabilities (SWD).

According to national and state standards, all students should be able to use grade-band level complex informational text (e.g., Next Generations Science Standards [NGSS]; CCSS-ELA-Reading in Science and Technical Subjects [RST]). However, for many students, in particular SWD, this can be an extremely difficult task. Students with disabilities have various challenges with grade-band level complex informational text, including difficulty with text structure, lack of background knowledge to understand concepts, difficulty with technical vocabulary, and lacking comprehension skills such as inferencing (Mason & Hedin, 2011; Saenz & Fuchs, 2002). As a result, instruction with such texts is often avoided, but this compromises student learning, especially for SWD (Litman & Greenleaf, 2018; Shanahan, 2020). All the teachers are required to use that anchor text as a part of the multimodal STEM text set instruction, with the aim that students are to engage with the text. Our research program is focused on examining the impact of this expectation with all learners and, in particular, SWD.

To date, we have collected and analyzed data from three cohorts of teachers (N= 25) that have implemented a multimodal STEM text set in their classroom(s). Data (N >700 students; 15.6% students with disabilities) collected using a pre-posttest design with a scenario-based assessment indicates that both SWD and students without disabilities (SWOD) made significant and quantitatively similar gains in argumentation practices and self-efficacy. Importantly, gains for SWD occur in the general education classroom (Lannin et al., in press; Romine et al., in press; van Garderen et al., in press).

Exit Slips

One simple way to gather knowledge about students' engagement in and understanding of a lesson is via use of exit slips. Typically, an exit slip is collected via "an index card or piece of paper on which individual students respond to a prompt from the teacher" (Marzano, 2012, p.80). More recently, instructors have been implementing exit slips using technology (Kirzner, et al. 2021). These can be applied at the end of a lesson and require little time (Fisher & Frey, 2004). Exit slips can serve four important functions: (1) gathering formative assessment data on learning, (2) allowing learners to self-reflect on learning, (3) providing feedback on teaching practices, and (4) allowing for interaction with the teacher (Basco 2021; Marzano, 2012). Importantly, exit slips can serve as formative assessments to help teachers adjust teaching, to help students be successful learners (Windschit et al., 2012). In a study by Snodgrass et al., (2017) the most commonly used formative assessments by science teachers in grade 5-8 were exit slips.

Not only have exit slips served as formative assessment for teaching and learning, but they have also successfully been used as an instrument for data collection (e.g., Monrat, et al. 2022). The value of a practical measure such as an exit slip is that it can be collected without excessive burden. It captures more ecologically valid forms of learning (Anderson & Richard, 2021).

Purpose of the Current Study

To date, we have collected extensive data as to the effectiveness of using multimodal STEM text instruction by teachers to engage learners (Lannin et al., in press) and improve student outcomes in argumentation (Romine et al., in press; van Garderen et al., in press). No data have been collected on students' perceptions of their learning or the use of multimodal STEM text set instruction. Previous research has revealed associations between high-quality instruction and student learning as well as motivation and engagement (Allen et al., 2013; Havik & Westergard, 2020). Developing an understanding of how the students perceive multimodal STEM text set instruction will provide further evidence as to the effectiveness and efficacy of the instruction and where improvements may need to be made.

During the second year of the program, due to COVID-19, we pivoted from face-to-face meetings with teachers and paper and pencil data collection to completely online formats. Given this pivot, we recognized the opportunity to collect data directly from the students, including SWD as a part of their instruction during teacher implementation of the multimodal STEM text sets. The purpose of this study is to determine students' perspectives on instruction with multimodal STEM text sets. Specifically, to what extent do students with disabilities (SWD) perceive the quality of instruction with the multimodal STEM text sets and their learning as compared to students without disabilities (SWOD)?

Methods

The data reported here represent a subset of a quantitative and qualitative dataset collected during a year-long professional development designed to examine the effectiveness of the Linking Science and Literacy for All Learners program for teachers and students. The quantitative data includes exit slip and survey data (Likert scales). The qualitative data includes open-ended responses from the exit slips. We used a mixed methods convergence model (Creswell & Plano Clark, 2018) where findings (quantitative and qualitative) were converged and triangulated to generate conclusions.

Participants

Data were collected from 434 students of which 19% ($n=86$) were SWD, 54% ($n = 235$) were male, and 87% ($n = 376$) were White. Students were in middle school level grades 6th ($n=220$), 7th ($n=79$) and 8th ($n=135$). A summary of demographic information for each teacher participant ($n=6$) is found in Table 1.

Table 1. Student Demographic Data by Teacher

Teacher	Student Gender		Student Ethnicity		Students with IEP	ELL Students	Grade(s)		
	Males	Female	White	Non-White			6	7	8
1	52	42	71	23	10	0	-	-	94
2	10	14	19	5	0	6	-	-	24
3	32	14	33	13	46	0	18	11	17
4	55	59	100	14	16	0	98	16	-
5	32	29	59	2	2	0	61	-	-
6	54	41	94	1	10	0	43	52	-

Instructional Context

Six middle school teachers implemented their multimodal STEM text sets with their middle school students. Each teacher selected one anchor text as their focus for their multimodal STEM text set. Their selection is connected to a standard(s) that was to be taught during the academic year per district requirements. The teachers could implement the multimodal STEM text set at any time during the academic year; however, most implemented it during the spring semester. Using the anchor text along with recommended scaffold texts, the teachers developed their own multimodal STEM text set. The multimodal STEM text sets included the standards targeted, the learning objectives, inquiry-based lessons, the anchor text, resources, and materials for implementation with their students. Demographic information about the teachers can be found in Table 2.

Table 2. Teachers' Demographics, Text Set Focus, and Exit Slip Implementation

Teacher	Text Set Focus	Ethnicity	Certification	Grade(s) Implemented	Setting	Exit Slip Days of Entry
1	Vaping	White	Science/STEM	8	Suburban	3
2	Vaping	African American	English Language Art	8	Suburban	7
3	Vaping	White	Special Education	6, 7, 8	Suburban	3
4	Vaping	White	Science/STEM	6, 7	Suburban	18
5	Earth and Human Activity	White	Science/STEM	7	Suburban	8
6	Earth and Human Activity	White	Science/STEM	6, 7	Rural	9

Measures and Data Collection Procedures

Two measures were used in this study: (a) exit slip, and (b) confidence in argumentation survey. The exit slip resulted in quantitative and qualitative data whereas the confidence in argumentation survey resulted in quantitative data.

Exit Slip Ticket. Data were collected by an electronic “exit slip” designed by the project research team. The exit slip consisted of 5-point Likert scale items and 4 open-ended sentence starters. The Likert scale items included rating (a) today’s lesson, (b) my learning, (c) my understanding of claim-evidence-reasoning, and (d) my interest in the topic we studied today. Students were to give a 1 to 5 rating for each item where 1-star was the lowest and 5-stars the highest. In addition to the Likert scales, there were four open-ended sentence starters that the students were to answer. They were: (a) An important thing I learned today was ..., (b) An idea I am confused about is..., (c) Something I would like to change about today’s

learning..., and (d) [for online learners] I was able to get help from [e.g., family member, friend, website ...] to help me complete the lesson/task because.... The students were to choose 2 sentence starters and complete them.

To implement the exit slips, the teachers were provided a Google survey link that they were to embed within their instruction (end of a lesson or task) at a minimum of 3 points during their implementation of their multimodal STEM text set. The teachers could choose when to collect the data; however, they were encouraged to collect it at some point in the beginning, middle and end of their text set implementation. To encourage the use of exit slips as formative assessments for the teachers themselves, all exit slip responses were made available to the teacher immediately after completion. Of the six teachers, four teachers completed an exit slip for a lesson that incorporated the anchor text. Two teachers completed the exit slips after having used the anchor text at least two times prior to completing the exit slips. A total of 2276 exit slips were collected (range 111-1289 responses for each teacher).

Confidence in Argumentation Survey. Five items were used to assess confidence in argumentation which were measured on a 4-level Likert scale: Strongly Disagree, Disagree, Agree, and Strongly Agree. Using these five items, the measure for Confidence in Argumentation showed a Rasch reliability of 0.72. Factor 1 of the residuals with respect to the Rasch Rating Scale Model had an eigenvalue of 1.32, justifying the assumption of unidimensionality. The item “It is important to justify what you say” was the easiest to agree with. The most difficult item was “I am good at finding flaws in my own arguments”. Moderate difficulty items included: “I am good at finding evidence to support my arguments”; “The arguments I make are logical and evidence-based”; and “I am good at pointing out the flaws in other people’s arguments.” Analysis of misfit with respect to the Rasch Rating Scale Model suggests that the five items show expected fit with the Rasch model (infit between 0.91 and 1.07; outfit between 0.88 and 1.03) which suggests that all items are informative measures of students’ confidence in argumentation.

Data Analysis

Statistical analyses. To analyze the differences in the Likert scale scores from the exit slips between SWD and SWOD, we used an independent samples t-test. Given that Likert data tend to be non-normal, we calculated 2-tailed p-values based on standard errors derived from 10,000 bootstrap samples stratified by IEP status using the bias corrected and accelerated method. The 95% confidence level (2-tailed) was used to determine statistical significance. Equal variances were not assumed since the outcomes failed Levene's test for equal variances (p-values less than 0.05 indicating significant difference in variances between groups).

Data from the confidence survey were analyzed using repeated measures ANOVA on a pre-post design. The between-subjects model included IEP status and the within-subjects model included Time and the IEP status x Time 2-way interaction. The statistical significance of these effects was evaluated at the 95% confidence level.

Machine Learning analyses. Data collected from the open-ended starters were analyzed using natural language processing, a machine learning method. ‘Machine learning’ is a broad class of methods by which a machine can learn the structure of data in order to make meaningful predictions within new contexts. One of the simplest machine learning models is a simple ‘line of best fit’ that we teach students in their math and science classes. Assuming the relationship between a predictor and an outcome is linear, the line of best fit can be used to make useful predictions in new contexts.

Topic modeling is a machine learning method used in natural language processing to extract meaningful themes from text. We used Latent Dirichlet Allocation (LDA; Blei, Ng, & Jordan, 2003) a popular method for learning and identifying the hidden themes in text such as

students' writing. We implemented separate LDA models on students' writing about *what they learned when using the text sets* and *aspects of the text sets that they found confusing*.

There were a total of 2026 documents related to both *what students learned* and *aspects they found confusing* with 125 and 399 empty documents respectively. Additionally, 2 documents from 'learned' and 8 documents from 'confused about' contained only punctuation. So, we removed a total of 127 and 407 documents from these two fields respectively before fitting our LDA model.

Data preprocessing. Before implementing LDA, we first preprocessed the text by removing punctuation and stop words (words that occur very commonly and therefore tend to be non-informative) from the text. In the same spirit, we removed words like 'learn', 'learned', and 'learning' from text related to *what students learned* and words like 'confuse', 'confused', and 'confusing' from text related to *aspects which were confusing*. Then we lemmatized the text to convert the words to their base root mode. For example, words like "argue", "argued", "argues", would be shortened to "argue" so that these very similar variations are treated the same way by the model. We then converted the text into a spreadsheet using a "bag of words" representation which indicates whether or not a word is present in a student's response by counting the number of times it occurs in the response.

Fitting and interpreting the LDA model. To train separate LDA models on text related to *what students learned* and *aspects they found confusing*, first we identified the optimal number of topics within the set of responses corresponding to each respective question separately using the gensim coherence model (O'Callaghan et al. 2015). A coherence score measures the semantic similarity between the words in a topic. Toward optimizing the balance between fit and parsimony, our goal was to find the number of topics for which the coherence score was locally maximized for a relatively small number of topics. After finding the optimal number of topics for both fields based on their coherence plots, we trained the LDA model for both fields separately and labelled each text entry with the dominant topic. Each topic was then given a particular qualitative theme based on the most commonly occurring words within that topic and by looking at some of the representative responses corresponding to that topic.

Results

To report the results, we organize them around the two main parts of our research question: the student's perception of (1) quality of instruction, and (2) their learning. Data are reported for all learners and, more specifically, comparing SWD to SWOD.

Quality of Instruction. Two items on the exit slips focused on perceived quality of the lesson. Students were asked to rate the lesson and their interest in the topic. For all students, the ratings positively favored the lesson and their interest in the topic (Rate lesson: $M=3.83$ [$SD=1.12$], median=4; Interest in topic: $M=3.47$ [$SD=1.22$], median=4). Comparisons between SWD and SWOD for both items revealed no statistically significant difference between groups suggesting that both groups of students perceived the lesson similarly. See Table 3 for a summary of the results.

Table 3. Exit Slip Likert Scale Ratings Between SWD and SWOD

Exit Pass	SWD mean (SD) (n = 86)	SWOD mean (SD) (n = 348)	p-value ^{a,b}	Cohen's D	Effect Size
Rate Lesson	3.58(1.38)	3.89(1.04)	0.053	0.25	Small
Rate Learning	3.45(1.32)	3.70(1.07)	0.109	0.21	Small
CER Understanding	3.34(1.23)	3.94(0.97)	< 0.001	0.54	Moderate
Interest in Topic	3.30(1.38)	3.51(1.17)	0.195	0.16	Negligible

^aCalculated using the bias-corrected and accelerated (BCa) method based on 10,000 bootstrap samples stratified by SWD status

^bEqual variances not assumed

Perceived Student Learning. Perceived learning was measured via the exit slips (Likert scales and open-ended statements) and the Confidence in Argumentation Survey. We report findings for each measure.

Exit slips – Likert scales. Two items, rate learning and CER understanding, examined perceived learning of the lesson. For all students, the ratings positively favored the lesson and their interest in the topic (Rate learning: $M=3.65$ [$SD=1.13$], median=4; CER Understanding: $M=3.82$ [$SD=1.06$], median=4). Comparisons between SWD and SWOD for “Rate Lesson” revealed no significant difference. However, the item “CER Understanding” was statistically significant between groups (see Table 3 for summary). The SWD had a statistically lower average rating for CER Understanding in comparison to SWOD.

Confidence in Argumentation Survey. Through the repeated measures ANOVA procedure on a pre-post design, we found that engaging with the text sets significantly improved the students’ confidence in argumentation ($F_{1,368} = 5.62$, $p = 0.018$, $\eta^2_{\text{partial}} = 0.015$), and that there was no significant difference in the degree of improvement between students on IEP’s and those not on IEP’s ($F_{1,368} = 1.13$, $p = 0.288$, $\eta^2_{\text{partial}} = 0.003$, see Figure 1). Students on IEPs began the instruction with a confidence measure of 0.26 logits ($SD=1.4$) which climbed to 0.58 logits ($SD=1.5$) at the end of the instruction. This amounted to a standardized mean difference of 0.21. The gains of the remaining students were more modest; they started at 1.54 logits ($SD=1.5$) and ended up at 1.66 logits ($SD=1.6$) which amounted to a standardized mean difference of 0.076. Although these differences are relatively small, they are nonetheless important in the sense that a psychological construct like confidence which is built over a student’s entire life is not easy to change with a brief duration of instruction. These findings show that the text sets moved students’ confidence in a positive direction despite its inherent resistance to change.

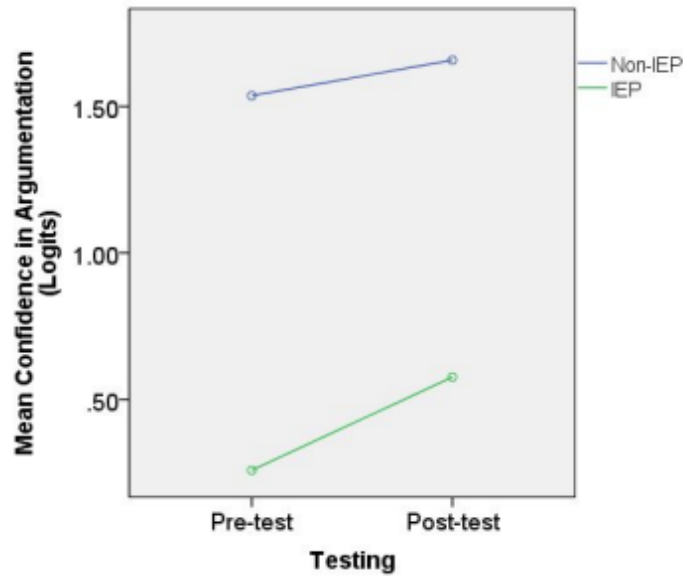


Figure 1. Mean Level of Confidence in Argumentation for SWD (IEP) and SWOD (non-IEP)

Exit Slips – Open Ended Sentence Starters. A local maximum in the coherence score for both *what students learned* and *aspects they found confusing* showed that 7 topics were optimal for identifying the themes in each set of responses. So, we trained our LDA models on these two sets of responses separately with 7 as the number of topics. Tables 4 and 5 summarize the topics for SWD and SWOD.

Table 4. Machine Learning “Learned About” Qualitative Responses

Topic SWD	# Entries	Topic SWOD	# Entries
1 Changes on climate and lungs	101	Changes on climate	390
2 Argumentation (CER)	26	Argumentation (CER)	249
3 Greenhouse effect, temperature, death	18	Chemical effects	216
4 Make poem, journal	23	Greenhouse effects	258
5 Smoking Causes	34	Smoke, lungs	184
6 Negative effects on heart – cancer	20	Heart rate increase	146
7 Nicotine on the body	29	Effects of nicotine	205

Table 5. Machine Learning “Confused About” Qualitative Responses

	Topic SWD	# Entries	Topic SWOD	# Entries
1	Confusion about task – rolling journal (time)	157	No confusion	711
2	People, smoke	35	People, know	172
3	Lesson concerns	13	Reasoning	88
4	Main ideas –	15	Climate change	116
5	Confusion about task – poem, math, paper	13	People, heart, poem	105
6	Content related - market, sympathetic	12	People – lung & brain	105
7	Content related – global impact, flooding, temperature	8	Impact of nicotine	69

Regarding what was learned (Table 4), we see many of the same themes showing up for SWD and SWOD. Topic 4 is an exception, where we found that SWD seemed to be impacted by the creative and reflective writing practices integrated into the lessons. Otherwise, student-reported learning was primarily aligned with the underlying content of the text set. Although this can be considered an expected result, it nonetheless confirms that students felt like they were mastering the underlying content which is a promising outcome.

Within aspects students found confusing (Table 5), the most noticeable contrast between SWD and SWOD was in Topic 1 (confusion about the task). Here, SWOD reported little-to-no confusion whereas SWD consistently felt confused about what was expected from the rolling journal. We also see this trend in Topic 3, where SWD noted confusions about the learning tasks whereas SWOD confusions rested within the content itself.

Discussion

The use of instruction such as multimodal STEM text sets as a way to increase access to complex science text has become a necessity. The Next Generation Science Standards (NGSS) has stressed the importance of developing scientifically literate citizens and increasing interest in the STEM field for future generations (NGSS, 2012). In response, educational initiatives and research have been conducted to address these needs (Krajcik, 2015). This study examined the perceptions of students’ (with and without disabilities) engagement with multimodal STEM text sets designed to support development of disciplinary literacy skills.

Taken together, the findings suggest that both SWD and SWOD rate the quality of the lessons and their learning similarly, which highlights the efficacy of multimodal STEM text sets in motivating and empowering a diverse student body. This finding is particularly encouraging for SWD in connection to reading scientific text. A prevailing notion exists that one way to improve adolescent readers’ text comprehension or comprehension ability is by providing easier text (Lupo et al., 2019). Further, it has been suggested that using complex text may be harmful to motivation and engagement (Shanahan, 2019). Recent research suggests that this is not the case and, importantly, when provided supportive instruction,

challenging texts can be accessible to SWD (e.g., Lupo et al., 2019; O'Connor, Swanson, & Geraghty, 2010). Unique to this study is that the SWD themselves reported learning from the multimodal STEM text instruction and rated the lessons to be of benefit. SWD can engage in and learn from complex text. As Shanahan (2019) notes, "Restricting students to easier materials ... may serve to isolate these children from their social peers. These students are also aware that they are being relegated to the "dumb books," with serious consequences to their self-esteem" (p. 19).

Although the data generally supported similar perceptions of multimodal STEM text instruction for SWD and SWOD, there were two concerns for SWD that emerged that warrants discussion. First, the exit slip Likert scale for CER Understanding suggested that SWD understanding was not as strong as SWOD. Argumentation as a practice can be difficult for all students (Kuhn, 2010); however, from the limited research available argumentation can be even more challenging for SWD requiring more comprehensive instruction that addresses this practice (De La Paz & Levin, 2018; Levin et al., 2021; Romine et al., in press). Similarly, our findings suggest the need to have teachers build in additional instructional supports in argumentation for SWD.

Second, unlike SWOD who were more likely to express no confusion with the lessons, SWD expressed concerns regarding tasks they were to complete in particular tasks that involved writing (e.g., rolling journal, poem). Students with disabilities have been observed to experience significant challenges with expository writing including planning, revising, and editing as well as with specific writing skills such as spelling, mechanics, and transcription (De La Paz, 1999; De La Paz & Levin, 2018; Levin et al., 2021). This is something to keep in mind as we continue to implement these types of reflective writing activities—it might be productive to give SWD more attention and scaffolding; for example, focused explicit instruction on how to plan, revise and self-monitor writing (e.g., Mason et al., 2011).

Limitations and Future Research

Although the findings in this study demonstrate the efficacy of the multimodal STEM text set instruction for both SWD and SWOD there are a few limitations that need to be taken into consideration. First, the use of exit slips and surveys rely on self-report and, therefore, it is assumed what is reported is honest in response. No follow-up interviews or observations were conducted to verify student perspectives of the lesson and their understanding of what was learned. Relatedly, not all the teachers had students complete an exit slip for a lesson that involved the use of complex text, particularly the anchor text. However, all the students were engaged in lessons that were a part of the multimodal STEM text set when they completed the exit slips. We recommend the need for more research that uses additional measures and continues to explore student perceptions specifically in connection to the anchor text. Taking these perspectives into consideration will help teachers and researchers in improving students' learning and engagement.

Conclusion

This research sheds light on the impact of using multimodal STEM text sets from the students' perspectives, and differences in how SWD and SWOD perceive this type of instruction. It is essential to make meaningful science instruction accessible to all types of students including SWD. Engagement in active learning focusing on scientific text along with practices related to reasoning and argumentation can be challenging for both the students and the instructor. However, supportive instruction can make a difference. The use of exit slips provided critical information for teachers and researchers about the students' current levels of understanding and perceptions of the instruction.

Acknowledgements

This work was supported by NIH SEPA grant 8 R25 GM 129228-02, and the participating teachers and students. The views expressed are those of the authors, and do not necessarily reflect the views of the NIH.

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