The Advocate

Volume 29
Number 2 *Fall-Winter 2024*

Article 3

December 2024

Supporting Written Scientific Explanations of Middle-School Students with Learning Disabilities

Brooke A. Moore
Fort Hays State University, brooke.moore@fhsu.edu

Steve J. Skoczek
Fort Hays State University, steve.skoczek@kckps.org

Hannah W. Wince
Fort Hays State University, hewagner@mail.fhsu.edu

Recommended Citation
Moore, Brooke A.; Skoczek, Steve J.; and Wince, Hannah W. (2024) "Supporting Written Scientific Explanations of Middle-School Students with Learning Disabilities," *The Advocate*: Vol. 29: No. 2.
https://doi.org/10.4148/2637-4552.1197

Supporting Written Scientific Explanations of Middle-School Students with Learning Disabilities

Abstract

Students with learning disabilities deserve high-quality science instruction that supports them in constructing scientific explanations as a means toward building their science content knowledge. We examined written scientific explanations of 66 middle-school students with learning disabilities from rural Kansas school districts, comparing them with a matched set of 66 peers without learning disabilities within the same classrooms following instruction using a Next Generation Science Standards (NGSS) aligned curriculum that embedded explicitly taught supports for writing scientific explanations. Students were assessed at pre- and post-unit on overall content learning and change in written scientific explanations. Post-unit written explanations of students with learning disabilities were statistically significantly better following instruction but overall content knowledge gains were only practically significant. Differences between post-unit written explanations of students with learning disabilities compared to their peers without learning disabilities were not statistically significantly different, yet students without learning disabilities did show statistically significant growth in overall content knowledge.

Keywords

content instruction, science instruction, learning disabilities, general education

Cover Page Footnote

This work was supported by the National Science Foundation Grant Award 1908937.

Supporting Written Scientific Explanations of Middle-School Students with Learning Disabilities

Brooke A. Moore, Fort Hays State University
Brooke A. Moore, Ph.D., is an Associate Professor in the Advanced Education Programs Department in the College of Education at Fort Hays State University in Hays, Kansas. Formerly a special educator working primarily with students with high-incidence disabilities, her research focuses on helping educators create equitable and inclusive learning environments for all students by using evidence-based instructional practices.

Steve J. Skoczek, Fort Hays State University
Steven J. Skoczek, Ed.D., is a Special Education Teacher at Gardner-Edgerton High School in Gardner, Kansas. Working as an administrator with high-incidence special education students led him to return to the classroom, where he has a larger impact on student learning.

Hannah W. Wince, Fort Hays State University
Hannah W. Wince is a Gifted Education Facilitator with Hays Unified School District in Hays, Kansas. Before working with gifted students in schools, she was a high school biology teacher.

Introduction

Students with learning disabilities deserve high quality science instruction that will support them in becoming scientifically literate citizens (McNeill & Krajcik, 2007). The National Joint Committee on Learning Disabilities (NJCLD; NJCLD, 1990) defines a learning disability as a significant difficulty in acquiring listening, speaking, reading, writing, and math abilities. All of these are skills that are needed to engage in science content learning. NJCLD goes on to state that students with learning disabilities should have access to high-quality instruction but will need evidence-based supports and strategies to engage equitably with grade-level peers. In a review of the 2011 National Assessment of Educational Progress (NAEP) science scores, McGrath and Hughes (2018) noted that students with learning disabilities scored one standard deviation below their peers without disabilities. Data from the 2019 NAEP science assessment (National Center for Education Statistics, 2019) indicated the trend had not changed, with a statistically significant gap for students with learning disabilities of 32 points below students without disabilities.

In 2013, the Next Generation Science Standards (NGSS) were developed through a partnership with the National Research Council (NRC), the National Science Teaching Association (NSTA), the American Association for the Advancement of Science (AAAS), Achieve, and 26 lead states (NGSS Lead States, 2013). NGSS calls for science educators to design learning that helps students make sense of phenomena through three dimensions: integrating science and engineering practices, crosscutting concepts, and disciplinary core ideas. Three-dimensional learning leads to the development of deep, useable understandings of big ideas that students can apply to explain phenomena and solve real-life problems (Kaldaras et al., 2020).

While the NGSS provides a new vision for science education, implementation has proven challenging, particularly in geographically dispersed rural regions, such as Kansas, where this study occurred. Many districts in these regions may lack NGSS-aligned curricula and professional development in how to teach using these instructional practices (Penuel et al.,2015). While much is currently being done to design and evaluate curriculum, assessments, and instructional practices using NGSS, little is known about the effect on students with learning disabilities.

Our study aimed to examine the change in content knowledge of middle-school students with learning disabilities in rural Kansas school districts following instruction in a general education science classroom where their teacher used a proven, NGSS-aligned curriculum with professional development support. In particular, we examined the change over time in students' written scientific explanations. This is relevant as the NGSS supports the idea that *all* students should receive equitable access to high-quality science instruction. As Tang (2015) argued, if students are not successful in meeting disciplinary literacy needs, they are less capable of succeeding academically, economically, and professionally in our modern, knowledge-based economy. Many newly developing career pathways are in science, technology, engineering, and math (STEM) fields and these careers require sophisticated discipline-specific language and literacy skills.

Literature Review

Middle-school science instruction primarily focuses on developing disciplinary literacy in science. Shanahan and Shanahan (2012), in their seminal work, defined disciplinary literacy as "an emphasis on the knowledge and abilities possessed by those who create, communicate, and use knowledge within the disciplines" (p. 8). Torgesen et al. (2017) guided educators in supporting students in developing academic literacy, which is literacy across academic content areas. For them, academic literacy was defined as the ability to learn from texts, specifically, the "reading proficiency required to construct meaning of content-area texts and literature encountered in school" (p. 3). As Schoenbach and Greenleaf (2009) noted, reading disciplinary texts is key to gaining disciplinary knowledge, such as what students need to learn in science.

However, reading, or more importantly, comprehending disciplinary texts, is not enough for students to fully understand science concepts. The National Research Council (NRC: NRC, 2012) defined scientific "inquiry" as multiple ways that students can develop scientific content knowledge and how it relates to their world, not just through reading. Inquiry processes involve reading disciplinary texts, but also involve making observations, analyzing data and then discussing findings to co-construct answers. As Jones and Burrell (2021) noted, inquiry-based science education engages students in constructing explanations, discussing those explanations by using evidence, and disciplinary writing, a vital part of disciplinary literacy.

NGSS builds on prior work in science education with a distinct focus on integrating students' understanding of science as a holistic body of knowledge as well as a set of practices for how to develop that knowledge (Penuel et al., 2015). NGSS moves beyond traditional inquiry-based learning by urging educators to design learning experiences that actively engage students in cognitive, social, and physical practices. As noted in the NGSS Lead States (2013), "Students cannot comprehend scientific practices, nor fully appreciate the nature of scientific knowledge itself, without directly experiencing those practices for themselves" (p. xv).

As the field of science education evolves, there are certainly positive outcomes for many students. However, research consistently indicates that students with learning disabilities may not be getting equitable, high-quality science instruction (Colley & Lassman, 2021; Jones & Burrell, 2021). If teachers are not equipped or supported in using NGSS, students may struggle to understand basic scientific concepts. Students with learning disabilities need science teachers who understand how to design learning that is: (a) student-centered (Kang & Keinonen, 2018), (b) focused on one disciplinary core idea and the cross-cutting themes related to that core idea (Herrmann-Abell et al., 2016), (c) actively engaging them in discussing their thinking with peers (Nordine et al., 2021), and (d) strategically supporting them to scaffold their ability to develop and write scientific explanations (Levin et al., 2021).

McGrath and Hughes (2018) conducted a case study of six middle-school students with learning disabilities and their general and special education teachers. The students were taught a structured inquiry unit on ecology and submitted portfolios of their classwork at the end of the unit. Their portfolios were then reviewed for inquiry processes, and interviews were conducted with students and their teachers. Findings indicated that students generally struggled throughout the unit to identify scientific questions related to tasks they were asked to do, yet they were able to plan and carry out investigations. Overall, participants continued to struggle with inquiry processes used to develop disciplinary knowledge. A recommendation gained from this work is the value of supporting teachers in providing explicit structures and supports that involve ample teacher-guided peer discussions.

In their work in high school chemistry classrooms, King-Sears and Johnson (2020) found that general educators' use of Universal Design for Learning (UDL) produced statistically significant growth for students with learning disabilities. In their study, they compared students with and without learning disabilities in co-taught general education classrooms across conditions: UDL instruction versus business as usual. Using pre- and post-instruction content knowledge assessments, they found that students with UDL instruction scored higher, regardless of disability classification. From this work, it is evident that the use of graphic organizers and printed strategy support guides are valuable in supporting students with learning disabilities in understanding disciplinary core ideas.

Levin et al. (2021) examined the use of cognitive apprenticeship models with seventh-grade science teachers to support their students with learning disabilities in the general education classroom. Teachers explicitly taught a heuristic for constructing and critiquing scientific explanations (e.g., remember what you know, construct an explanation, consider an alternative, critique your explanation). Overall, they found that students' writing improved with more attention to reasoning (e.g., argumentation with the use of evidence) and improved grammatical sophistication. Thus, science teachers should create more opportunities for students to work collaboratively with teachers modeling how to critique written scientific explanations.

Writing claims, or scientific explanations, is a key NGSS-aligned practice. While writing can be challenging for all students, it is particularly daunting for students with learning disabilities. Often, students with learning disabilities struggle with working memory, processing, and information recall (Gillespie & Graham, 2014), organizing ideas (Benedek-Wood et al., 2014), and foundational writing skills (e.g., grammar, mechanics, spelling; Graham et al., 2015). Furthermore, writing scientific explanations is a different writing genre with unique text structures (e.g., argumentation, providing evidence) and specific vocabulary. When educators support students in writing a constructed claim through evidence and reasoning, students develop content knowledge and a deeper understanding of scientific phenomena (McNeill & Martin, 2011). Middle-school general education science teachers can support students with learning disabilities by embedding supports in their instruction that guide students in how to write claims by drawing on key science ideas and evidence from hands-on modeling and data analysis (Herrmann-Abell et al., 2016). Supporting claim development is then enriched when teachers provide direct instruction in how to evaluate claims, both their own claims as well as classmates, using explanation criteria (Moore & Wright, 2023). As noted by the NRC (2012),

> Asking students to demonstrate their understanding of the implications of a scientific idea by developing their own explanations of phenomena, whether based on observations they have made or models they have developed, engages them in an essential part of the process by which conceptual change can occur (p. 68-69).

Constructing explanations of disciplinary core ideas, specifically written ones, develops students' disciplinary literacy in science, is a scientific practice, and is a vital part of the inquiry process.

Research Questions

In our study, we examined the change in written explanations of students with and without learning disabilities following an NGSS-aligned curriculum that embeds explicitly taught structures and supports for guiding students in constructing written scientific explanations. Explicit instruction is an evidence-based, effective instructional practice, also considered a High-Leverage Practice by the Council for Exceptional Children (Council for Exceptional Children, 2024), that has been shown to improve student outcomes, particularly for students with learning disabilities. Our hypothesis was that developing students' ability to write claims would impact their overall content knowledge related to the curriculum taught. Our research questions were as follows:

1. To what extent did the NGSS-aligned curriculum and supports change the written scientific explanations for students with learning disabilities?
2. To what extent did the written scientific explanations of students with learning disabilities compare to the written scientific explanations of students without learning disabilities?
3. What is the impact of improved written scientific explanations on overall content knowledge growth?

Methods

DOI: 10.4148/2637-4552.1197

The larger research study, funded by the National Research Foundation, from which this project emerged, was situated in western Kanas, targeting middle-school science teachers in rural, geographically dispersed school districts (Moore et al., 2023). Following Institutional Review Board approval, 40 participating general education, middle-school science teachers were provided professional development in the use of the *Toward High School Biology (THSB)*, an NGSS-aligned curriculum that addresses learning across three dimensions related to understanding growth in living things (Herrmann-Abell et al., 2016).

In their original work, Herrmann-Abell et al. (2016) developed, implemented, and tested the effectiveness of *THSB*, which uses NGSS's three dimensions to guide students in applying chemistry ideas to living and nonliving contexts. Following professional development with three eighth-grade science teachers who then implemented the unit, they examined student learning as compared with three business-as-usual eighth-grade science classrooms. Findings from their work indicated that students who were taught with the *THSB* unit performed better on post-test outcome measures and demonstrated fewer common misconceptions.

THSB is presented as a unit that consists of 19 lessons taught over a six-week time period. The focus of the unit is to guide students in making connections across science disciplines. In particular, students learn to make connections between core ideas about chemical reactions to core ideas about biological growth and repair in plants and animals. The unit has embedded supports that guide students to write claims using a Claim, Evidence, and Reasoning Framework (McNeill & Krajcik, 2007, see Appendix A), focusing their attention on key science ideas and evidence from hands-on modeling (e.g., ball and stick models, LEGO models) and data analysis. Students are introduced to the idea of writing explanations in the second lesson in the unit and then given explanation quality criteria questions to ensure that their claim fully answers the question asked. In the third lesson of the unit, students use the explanation quality criteria questions to evaluate an example claim and then improve it (see Appendix). Throughout the unit, they investigate phenomena, use models to support core ideas (e.g., ball and stick, LEGO), analyze data that they have collected or that they are given, discuss findings with each other, and write explanations of the phenomena they are exploring.

Using a mixed methodology, this study examined the pre- and post-unit content knowledge assessments of students with and without learning disabilities over the course of the unit taught in their middle-school science classroom. In particular, we examined their written scientific explanation responses to items embedded within the assessment before and after their general education teachers taught the *THSB* unit.

Participants

Participants in this study were drawn from the larger study data set of 639 middle-school science students from 27 rural, geographically dispersed school districts in western Kansas whose teachers participated in the professional development and then taught the *THSB* unit. Within this study, 66 of the 639 students were identified with learning disabilities. This study examined the outcomes of those 66 students with learning disabilities with a matched set of 66 students without learning disabilities taken from the larger sample of participating students. The 66 students without learning disabilities were each matched with a student with a learning disability from the same teacher's classroom to capture individual teacher variation in instructional practices and then matched to demographics (e.g., grade level, gender, race/ethnicity, and primary language) to attend to as much variance between groups as possible.

Participants (n = 132) ranged in grade level, with 50 matched pairs in 6th grade (38%), 56 in 7th grade (42%), 22 in 8th grade (17%), and 4 in 9th grade (3%). Of the 132 participants, 48 matched pairs identified as female (36%) and 84 identified as male (64%); 110 identified as White (83%), 16 as Hispanic (12%), 4 as African American (3%), and 2 as Native American (2%); and 126 indicated their primary language as English (95%) and 6 indicate their primary language as Spanish (5%).

Data Collection

Data collected for our study included the Student Content Knowledge assessment taken by students online at the beginning of the *THSB* unit and following the conclusion of the unit. The Student Content Knowledge (SCK; Herrmann-Abell et al., 2016) assessment consists of 17 multiple-choice items and four constructed response explanation items related to the content of the *THSB* unit (e.g., the connection of chemical reactions to the biological phenomenon of growth). Using Rausch analysis, item separation reliability was established at 0.96 (Herrmann-Abell et al., 2016). The constructed response items required students to construct a claim based on evidence provided in the question (e.g., data tables, images). As part of the larger study, participating teachers were instructed to give students the pre-unit assessment immediately prior to beginning the unit and the post-unit assessment immediately after teaching the *THSB* unit. Constructed response items for the SCK were scored together by the larger study research team using a scoring rubric developed with the unit to ensure inter-rater reliability (Herrmann-Abell et al., 2016). The datasets analyzed during this study are available from the corresponding author upon reasonable request.

Data Analysis

Qualitative analysis was conducted for this study on the four constructed response items and included coding of students' written response items on the following: *length of written response*, *use of science vocabulary*, and *use of science ideas* linked to the *THSB* unit. To ensure inter-rater reliability, the authors scored fifteen matched pairs of participating students' written responses together and then met to confirm scores on the remaining items. *Length of written response* was a word count. For example, a student earned a length score of eleven for this written response, "The food that the sea star ate was made into arms." *Use of science vocabulary* was a qualitatively defined construct determined by the team during the first inter-rater reliability session and included the use of words that would logically appear in a middle school classroom and related to the *THSB* unit (e.g., atoms, molecule, mass, cell). Phrases that indicate a concept were counted as one vocabulary item (e.g., cell division, chemical reaction). Finally, during the *THSB* unit, students are introduced to 17 science ideas that were posted in their classrooms. When coding for the *use of science ideas*, the team qualitatively sought examples of students stating a science idea from the unit, both explicitly and implicitly. For example, a student wrote, "in a chemical reaction, atoms rearrange" which is *THSB* Science Idea # 2 (*Changes during* *which starting and ending substances interact to form new substances are called chemical reactions*.).

Quantitative data analysis examined change over time between pre- and post-unit student content knowledge scores and on the constructed response variables by group (e.g., students with or without learning disabilities) using paired sample t-tests of significance to compare means. Controlling for differences between groups at pre-test was assured by using Welch's ANOVA. Welch's ANOVA was chosen because it provides a more robust way of comparing two or more group means, particularly if data violate the assumption of homogeneity of variance (Kim & Cribbie, 2018). Conducting a Shapiro-Wilk test of normality (Singer et al., 2003), each pre-unit group mean was not statistically significantly different from normal. Finally, to examine changes at post-unit, an analysis of covariance (ANCOVA) was run to control for any pre-unit assessment differences.

Results

Our first research question examined the constructed responses of students with learning disabilities following instruction in an NGSS-aligned curriculum with embedded supports in how to write scientific explanations (see Table 1 for results). The length of constructed response summed across all four constructed response items increased for students with learning disabilities at post-unit (M = 59.08 words; SD = 29.15) compared with pre-unit (M = 44.08; SD = 31.49). This difference was statistically significant (p = 0.005). Students with learning disabilities improved their use of scientific vocabulary at post-unit (M = 4.77; SD = 3.65) compared with pre-unit (M = 2.03; SD = 1.93), which was a statistically significant difference (p = 0.000). Students with learning disabilities also stated more science ideas at post-unit (M = 0.35; SD = 0.65) compared with pre-unit (M = 0.08; SD = 0.27), which was also statistically significant (p = 0.001).

Table 1
Findings: Written Scientific Explanations of Students with Learning Disabilities

	Pre-*M*	Pre-*SD*	Post-*M*	Post-*SD*	Difference	Significance
Length	44.08	31.49	59.08	29.15	15.00	0.005
Vocabulary	2.03	1.93	4.77	3.65	2.74	0.000
Science Ideas	0.08	0.27	0.35	0.65	0.27	0.001

While we were interested in how students with learning disabilities responded to NGSS-aligned instruction guiding them in how to write explanations, our second research question compared the written explanations of students with and without learning disabilities (see Table 2 for results). Controlling for pre-unit scores, post-unit comparisons across groups indicated that students without learning disabilities wrote longer responses (M = 72.97 words; SD = 48.75) compared with students with learning disabilities (M = 59.08 words; SD = 29.15) summed across all four constructed response items. This difference of 13.89 words was not statistically significant (p = 0.34). Students without learning disabilities used slightly more scientific vocabulary (M = 5.03; SD = 3.87) compared with students with learning disabilities (M = 4.77; SD = 3.65) summed across all four constructed response items. This difference was not statistically significant ($p = 0.21$). Finally, students without learning disabilities stated science ideas ($M = 0.68$; $SD = 0.99$) slightly more than students with learning disabilities ($M = 0.35$; $SD = 0.65$), which was not a statistically significant difference ($p = 0.22$).

Table 2
Comparison of Written Explanations

	Students with LD		Students without LD		Difference	Significance
	Post-*M*	Post-*SD*	Post-*M*	Post-*SD*		
Length	59.08	29.15	72.97	48.75	-13.89	0.34
Vocabulary	4.77	3.65	5.03	3.87	-0.26	0.21
Science Ideas	0.35	0.65	0.68	0.99	-0.33	0.22

Our final research question examined how change in writing scientific explanations potentially influenced growth in students' overall content knowledge. Students with learning disabilities demonstrated slight overall growth with post-unit standard scores ($M = 1.35$; $SD = 0.95$) compared with pre-unit standard scores ($M = 1.15$; $SD = 0.93$), which was not statistically significant ($p = 0.21$). In comparing students with learning disabilities to their peers, students without learning disabilities also showed growth with post-unit standard scores ($M = 1.75$; $SD = 0.99$) compared with pre-unit standard scores ($M = 1.03$; $SD = 0.79$), which was a statistically significant difference ($p = 0.000$). It is interesting to note that students without learning disabilities demonstrated pre-unit scores that were slightly higher than their peers without learning disabilities. However, when controlling for pre-unit scores using ANCOVA, the difference between groups at post-unit (students with learning disabilities, adjusted $M = 1.34$; students without learning disabilities, adjusted $M = 1.76$) was statistically significant ($p = 0.01$).

Discussion

Our study supports the idea that providing explicit instruction and structured supports to guide students in writing scientific explanations, as embedded within an NGSS-aligned curricula, improves students' scientific content knowledge. Overall, for students with learning disabilities, the *THSB* unit proved to be a useful catalyst in improving their ability to develop and write longer claims using more scientific vocabulary and identifying more core science ideas. For all of the variables we identified in writing constructed responses (length, use of scientific vocabulary, stating science ideas) students with learning disabilities showed statistically significant growth at post-unit. Despite identifying significant change in written responses, students with learning disabilities did not show statistically significant growth on the overall post-unit content knowledge assessment.

While positive changes in written responses did not translate to significant improvements in overall content knowledge related to the unit, we did see growth that holds practical significance. For example, on an item asking students to describe the process by which atoms become part of a sea star's arms, one student with a learning disability responded on the pre-unit assessment, "When the sea star at [sic] food, it became energy, when it got energy, it funneled that into growing back the limbs using the mass it just gained from eating the food." Following the unit, the same student with a learning disability wrote:

DOI: 10.4148/2637-4552.1197

> I believe the mass came from the food the sea star ate. Science idea #16 states: The process by which proteins from food become part of animals' body structures involves chemical reactions in which the proteins from food are broken down into amino acid monomers, and these monomers are used to build different protein polymers that make up body structures. Atoms are rearranged during both the breakdown and the building of protein polymers. This proves that the sea star was able to break down food and use its mass for its own body.

The difference in the written response at post-unit demonstrates a deeper understanding of how chemistry and biology are linked. From having worked with ball and stick and LEGO models during the *THSB* unit, this student developed a better understanding of disciplinary core ideas, specifically that all substances are made from atoms that combine in various ways and that substances can form new substances as atoms are combined and rearranged. This student used considerably more science vocabulary in the post-unit response (e.g., amino acid monomers, protein polymers) and was able to link learning to a science idea learned from the unit.

While students without disabilities wrote longer sentences, used slightly more scientific vocabulary, and stated science ideas slightly more, those differences at post-unit were not statistically significantly different from their peers with learning disabilities. Embedding explicitly taught lessons in how to write explanations, providing students with criteria for then evaluating a claim, and consistently practicing how to write an explanation was, therefore, particularly relevant for students with learning disabilities in our study. This finding aligns with the work of Levin et al. (2021), who found that the written responses of students with learning disabilities improved with more use of argumentation, reasoning, and citing of evidence following explicit instruction and practice with a heuristic for writing scientific explanations. Similarly, King-Sears and Johnson (2020) found that the use of graphic organizers and printed strategy support guides positively impacted the conceptual understanding of their high school chemistry students with learning disabilities. Furthermore, students who received these supports, regardless of disability classification, outperformed students who did not.

Finally, one interesting discovery made in analyzing pre- and post-unit written responses of students with learning disabilities was the increased use of proper spelling and grammar, which was not something that we anticipated or purposefully examined. For example, when asked to compare perceived weights by looking at photographs of a piece of bread in a sealed plastic bag with and without mold, one student with a learning disability responded on the pre-unit assessment, "it is the same because bread wont [sic]change a weight because of mold." On the post-unit assessment, the same student responded, "The bag is sealed and when it is sealed it gains more weight because the mold is growing on the bread." A correct answer would describe a closed system (noted in the post-unit response), conservation of mass/matter, and no change in the number of atoms but a rearrangement of atoms/matter. While this student is developing a better understanding of closed systems, there is evidence of continued misconceptions regarding the conservation of mass/matter. However, the student's post-unit response was longer and utilized improved writing conventions. It is unclear, though, how improvements in writing conventions translate to enriched scientific learning over time.

Limitations and Future Research

Our study examined the pre- and post-unit assessments of students whose teachers were just teaching the *THSB* unit for the first time. As Penuel et al. (2015) have noted, using the NGSS framework requires a significant shift in teachers' instructional practices. This takes time and professional development support as well as teachers' familiarity and self-efficacy in teaching science using new instructional approaches and curricula. It is possible that when teachers present the unit the next time, they will do so with more fidelity to the curriculum, more attention given to student learning, and more redirection to clarify misconceptions. As McGrath and Hughes (2018) suggested, teachers should provide more explicit structures, supports, and teacher-guided peer discussions. As teachers become more familiar with the embedded supports in the *THSB* unit, their instruction may improve, and they may be more inclined to incorporate similar instructional practices (e.g., how to write scientific explanations, explanation quality criteria questions) across other units of study. Future research should examine how teachers' instructional practices change over time as they become more familiar with using NGSS-aligned curricula, assessments, and practices and the impact of these changes on the content knowledge of students with learning disabilities.

We also believe that supporting the writing of students with learning disabilities takes time, and determining the impact of that improvement in constructing written claims on overall content knowledge may take even longer. Our study followed students with and without learning disabilities over the course of the *THSB* unit, which averaged about six weeks. Perhaps, for students with learning disabilities, a more nuanced understanding of a constructed written explanation may eventually translate into a deeper understanding of the content over time. But it will take a much longer study to examine that reality.

Another limitation of this study was that special education teachers were not trained in the curriculum or the embedded supports for writing claims as part of the larger study. Therefore, it is unclear if students with learning disabilities who participated in this study received any additional support or practice in writing claims or in understanding the content of the unit. Future professional development in using NGSS-aligned curricula and instructional practices should be provided to special educators and support staff who work with students with learning disabilities in middle-school, general education science classrooms.

This study was conducted in rural areas of western Kansas with a small subset of a larger population of students. While our findings are certainly applicable to middle-school students with learning disabilities in this region of the US, they may not be generalizable to students with learning disabilities in different rural regions or suburban/urban areas.

Finally, our analysis of the data included a selection of a matched set of participants, all 66 of the students in the larger study with learning disabilities and a similar set of 66 without learning disabilities. We attempted to match participants on many variables (e.g., age, grade level, gender, race/ethnicity, language use), especially drawing matched sets from the same teacher to account for individual teaching practices across teachers. Therefore, we recognize that we could not account for all potential variables of differences across students, such as students' prior knowledge of science, individual learning styles, or even motivation to learn science.

Implications

While more research on the positive impact of NGSS-aligned curricula, assessments, and instructional practices is ongoing, our study provides guidance to both general and special educators on the importance of providing explicitly taught supports for developing and evaluating scientific explanations. Specifically, educators who work with students with learning disabilities in general education science classrooms should ensure that these instructional supports are embedded in any curricula used across the academic year. The continued, scaffolded use of a claim, science idea, evidence, and reasoning framework for writing their own scientific explanations and evaluating others' claims is a proven method for supporting a deeper understanding of science phenomena for students with learning disabilities.

While our study showed promise in developing written scientific explanations of students with learning disabilities, more research is warranted that involves students' use of the explicitly taught supports for a longer period of time and applied to other content units. Furthermore, the use of a pre-and post-unit design limited our ability to compare with a group of students who did not receive the NGSS-aligned curricula with instructional support. Thus, future researchers should design this study in broader contexts with the inclusion of a control group to assess the extent of the outcomes and to attribute such outcomes to the program or other potentially identifiable confounding factors.

Conclusion

Overall, our study demonstrated that the embedded supports to guide students in writing scientific explanations in an NGSS-aligned curriculum proved useful for students with learning disabilities. While their written explanations were statistically significantly better following the *THSB* unit, their overall content knowledge gains were only practically significant. And, while their post-unit written explanations were not statistically significantly different from their peers without learning disabilities, their peers did show overall content knowledge growth that was statistically significant. More research is needed to determine how improvements in writing scientific explanations translate to overall growth in content knowledge. We suggest that this happens over time as their general education science teachers become more familiar with using NGSS-aligned curricula and instructional practices and if they get additional support and practice from their special education teams.

References

Moore, B.A., Legleiter, E.F., Owens, K., Packard, B., & Wright, J. (2023). Evaluating the effectiveness of an online professional development for rural middle-school science teachers. *Journal of Science Teacher Education*, 35(4), 386-404. https://doi.org/10.1080/1046560X.2023.2287321

Moore, B. A., & Wright, J. (2023). Constructing written scientific explanations: A conceptual analysis supporting diverse and exceptional middle- and high-school students in developing science disciplinary literacy. *Frontiers in Education 8*. https://doi.org/10.3389/feduc.2023.1305464

Benedek-Wood, E., Mason, L. H., Wood, P. H., Hoffman, K. E., & McGuire, A. (2014). An experimental examination of quick writing in the middle school science classroom. *Learning Disabilities: A Contemporary Journal*, *12*(1), 69-92.

Colley, K. E. & Lassman, K. A. (2021). Urban secondary science teachers and special education students: A theoretical framework for preparing science teachers to meet the needs of all students. *Insights into Learning Disabilities, 18*(2), 159-186.

Gillespie, A., & Graham, S. (2014). A meta-analysis of writing interventions for students with learning disabilities. *Exceptional Children*, *80*(4), 454-473. https://doi.org/10.1177/0014402914527238

Graham, S., Hebert, M., & Harris, K. R. (2015). Formative assessment and writing: A meta-analysis. *The Elementary School Journal*, *115*(4), 523-547. https://doi.org/10.1086/681947

Herrmann-Abell, C. F., Koppal, M., & Roseman, J. E. (2016). Toward high school biology: Helping middle school students understand chemical reactions and conservation of mass in nonliving and living systems. *CBE—Life Sciences Education*, *15*(4), 1-21. https://doi.org/10.1187/cbe.16-03-0112

Jones, T.R. & Burrell, S. (2021). Present in class yet absent in science: The individual and societal impact of inequitable science instruction and challenge to improve science instruction. *Science Education, 106*(5). 1032-1053. https://doi.org/10.1002/sce.21728

Kaldaras, L., Akaeze, H., & Krajcik, J. (2020). Developing and validating Next Generation Science Standards-aligned learning progression to track three-dimensional learning of electrical interactions in high school physical science. *Journal of Research in Science Teaching, 58*(4), 589-618. https://doi.org/10.1002/tea.21672

Kang, J., & Keinonen, T. (2018). The effect of student-centered approaches on students' interest and achievement in science: Relevant topic-based, open and guided inquiry-based, and discussion-based approaches. *Research in science education*, *48*(4), 865-885. https://doi.org/10.1007/s11165-016-9590-2

Kim, Y. J., & Cribbie, R. A. (2018). ANOVA and the variance homogeneity assumption: Exploring a better gatekeeper. *British Journal of Mathematical and Statistical Psychology*, *71*(1), 1-12. https://doi.org/10.1111/bmsp.12103

King-Sears, M.E. & Johnson, T.M. (2020). Universal design for learning chemistry instruction for students with and without learning disabilities. *Remedial and Special Education, 41*(4), 207-218. https://doi.org/10.1177/0741932519862608

Levin, D.M., De La Paz, S., Lee, Y., & Escola, E.N. (2021). Use of cognitive apprenticeship models of instruction to support middle school students' construction and critique of written scientific explanations and arguments. *Learning Disabilities: A Multidisciplinary Journal, 26*(1), 58-72. https://doi.org/10.18666/LDMJ-2021-V26-I1-10380

McGrath, A.L. & Hughes, M.T. (2018). Students with learning disabilities in inquiry-based science classrooms: A cross-case analysis. *Learning Disability Quarterly, 41*(3), 131-143. https://doi.org/10.1177/0731948717736007

McNeill, K. L. & Krajcik, J. (2007). Inquiry and scientific explanations: Helping students use evidence and reasoning. In J. Luft, J. Gess-Newsome, & R. L. Bell (Eds.), *Science as Inquiry in the Secondary Setting* (pp. 121-134).

McNeill, K. L. & Martin, D. M. (2011). Claims, evidence, and reasoning: Demystifying data during a unit on simple machines. *Science and Children, 48*(8), 52-56.

National Center for Education Statistics. (2019). *Nation's report card. National Assessment of Educational Progress*.

National Joint Committee on Learning Disabilities (1990). *What are LD?* https://njcld.org/ld-topics/

National Research Council (2012). *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*. Washington, DC: The National Academies Press. https://doi.org/10.17226/13165.

NGSS Lead States. (2013). *Next Generation Science Standards: For States, By States.* Washington, DC: The National Academies Press. https://nap.nationalacademies.org/catalog/18290/next-generation-science-standards-for-states-by-states

Nordine, J., Sorge, S., Delen, I., Evans, R., Juuti, K., Lavonen, J., Nilsson, P., Ropohl, M. & Stadler, M. (2021). Promoting coherent science instruction through coherent science teacher education: A model framework for program design. *Journal of Science Teacher Education*, *32*(8), 911-933. https://doi.org/10.1080/1046560X.2021.1902631

Penuel, W. R., Harris, C. J., & DeBarger, A. H. (2015). Implementing the next generation science standards. *Phi Delta Kappan, 96*(6), 45-49. https://doi.org/10.1177/0031721715575299

Schoenbach, R. & Greenleaf, C. (2009). Fostering adolescents engaged academic literacy." In L. Christenbury, R. Bomer, & P. Smagorinsky (Eds), *Handbook of Adolescent Literacy Research*, (pp. 98-112).

Shanahan, T. & Shanahan, C. (2012). What is disciplinary literacy and why does it matter? *Topics in Language Disorders, 32*(1), 7-18. https://doi.org/10.1097/TLD.0b013e318244557a

Singer, J. D., Willett, J. B., & Willett, J. B. (2003). *Applied longitudinal data analysis: Modeling change and event occurrence*. Oxford University Press.

Tang, K.S. (2015). Reconceptualizing science education practices from New Literacies research. Science Education International, 26(3), 307-324.

Torgesen, J. K., Houston, D. D., Rissman, L. M., Decker, S. M., Roberts, G., Vaughn, S., Wexler, D. J., Francis, M. O., & Lesaux, N. (2017). Academic literacy instruction for adolescents: A guidance document from the Center on Instruction. *Center on Instruction*. RMC Research Corporation.

Appendix A

Sample Model for Writing and Evaluating Scientific Explanations

Constructing and Evaluating Scientific Explanations

	What is this?	Explanation Quality Criteria
Question	The question to be answered.	
Claim	A statement that answers the question.	Does the claim respond to the question?
Science Ideas	Accepted scientific ideas, concepts, or principles used to show why the evidence supports the claim.	Are the science ideas used relevant to the claim?
Evidence	Data that support the claim and can be confirmed. Data are based on observations that are made with our senses or measured with instruments.	Does the evidence support the claim?
Models	Tools for thinking about the world, like LEGO models, that can give you ideas about how something might work.	Are the models consistent with the science ideas listed? Do the models show that the claim is reasonable?

Adapted from McNeill, K.L. & Martin, D. M. (2011). Claims, evidence, and reasoning: Demystifying data during a unit on simple machines. *Science and Children, 48* (8), 52-56.
Adapted from American Association for the Advancement of Science (2017). *Toward High School Biology: Understanding Growth in Living Things*. National Science Teachers Association Press.

DOI: 10.4148/2637-4552.1197