LSHSS

Research Note

Complex Sentences in an Elementary Science Curriculum: A Research Note

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Purpose: Elementary school students are expected to participate in science learning settings that place high demands on skill with certain types of grammatical structures, including complex sentences. This research note aims to clarify the types of complex sentences that are evident in a general education science curriculum across the elementary school years in order to assist clinicians and others in better understanding the specific language demands of science learning in the classroom.
Method: I analyzed all sentences within children's texts and suggested teacher scripting from the first-, third-, and fifth-grade science units of a commonly used general education curriculum aligned to the Next Generation Science Standards. We determined the frequency and type of complex sentences that were present for each type of material (text, teacher scripts) and grade level.
Results: Complex sentences are evident in both children's texts and suggested scripting provided to teachers at all grade levels. The rate of complex sentences in children's readings is higher in third- and fifth-grade texts than in first-grade texts. Complement clauses are common throughout, and adverbial and relative clauses are more frequent in third- and fifth-grade texts than in first-grade texts.
Conclusions: Children are expected to read and listen to complex sentences across the elementary school years. Speech-language pathologists should be aware of the language demands that general education science curricula may pose to students at different ages.

Elementary school science instruction requires children to both read informational text and engage in expository discourse. The frequent use of complex syntax within science instructional settings may result in challenges for children with language disorders because this population tends to struggle with these types of linguistic structures (Marinellie, 2004; Schuele & Dykes, 2005). The link between difficulties with complex syntax and difficulties with academic achievement has been more broadly discussed in relation to older children and adolescents (Riches et al., 2010; Zwitserlood et al., 2015). However, children are expected to engage in science learning—including comprehension and production of the types of discourse associated with science—throughout the school years. Even in the early years, children are required to read informational text, listen to teacher talk, and express thoughts, concepts, and questions verbally. Speech-language pathologists (SLPs) who work in the public schools are charged with supporting access to the general education curriculum for children with language learning disabilities. However, SLPs will only be able to address these language demands if they are aware of the types of language demands within the curriculum. A deep understanding of the language demands of the curriculum will enable SLPs to better assess potential areas of difficulty for children on their caseload, consult with general education teachers about language supports that may be required for children, and select intervention targets related to classroom language demands. Thus, here I will examine the frequency and type of complex sentences used within an elementary school science curriculum in order to clarify the types of language used within elementary school science learning contexts.

Acquisition of Complex Sentences

Complex sentences are utterances that contain a main clause and at least one subordinate clause (e.g., "She observed that the kite flew in the wind." "The plants that were watered grew in the soil."), whereas simple sentences contain a single main verb (Diessel, 2004). Complex sentences can be further broken into those containing relative clauses, complement clauses, and/or adverbial clauses. Although SLPs may perceive complex sentences as an

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"older" skill, typically developing (TD) children are, in fact, starting to use these structures by the age of 3 years (Diessel, 2004), and thus, these sentence types are developmentally appropriate intervention targets even for fairly young children with language disorders (Arndt & Schuele, 2013). However, the developmental trajectory for these syntactic forms is quite long—children continue to exhibit gains in comprehension and production of increasingly complex sentences throughout the school years. Thus, in determining the relationship between science teaching settings and the demands placed on child language skills, it is essential to determine the frequency and type of complex syntax in use at different points across the elementary school period. Below, I briefly discuss each type of complex sentence of interest.

Relative Clauses

This type of complex sentence includes a main clause and an embedded/subordinate clause that modifies a noun from the main clause. Relative clauses can modify the subject or object of the main clause, as in the two examples below:

> Subject: *The students that were in my science class watered the plants.*
> Object: *The students watered the plants that were in the classroom.*

Relative clauses frequently differentiate between nouns (e.g., "The students that were in my science class watered the plants") particularly in written text. However, relative clauses may also provide additional information that does not disambiguate between nouns. For example, an individual may say "They watered the plants that were in the classroom" even without a need to distinguish between "plants in the classroom" and "other plants." Relative clauses emerge early in development but exhibit a protracted course of development in terms of both comprehension and production. Children with language disorders may exhibit later emergence and less frequent use of relative clauses into the elementary school years and even adolescence (Nippold et al., 2008).

Complement Clauses

Complement clauses may also be called "nominal clauses." This type of complex sentence includes a main clause (matrix clause) with a complement-taking verb and a complete clause that serves as the object of the verb from the main clause. Complement clauses typically occur with verbs of cognition, perception, communication, or desire, such as think, know, want, predict, or expect. Complement clauses may be nonfinite (not inflected for tense and agreement) such as "He expected the plants to grow tall" or finite (inflected for tense and agreement) such as "He predicts that the plants will grow tall." Complement clauses emerge prior to 3 years of age but exhibit an extended developmental trajectory. Over the course of the years following first emergence of complement clause use, children exhibit growth in the variety of verbs ("think," "know," "guess," "predict," "believe," "decide") and the syntactic complexity of complement clauses they produce (Kidd et al., 2006). Children with language disorder may be later to exhibit full complement clauses and may produce more errors in utterances containing complement clauses than their TD peers (Owen Van Horne & Lin, 2011).

Adverbial Clauses

An adverbial clause is a main and a complete clause that functions as an adverb modifying the verb, an adjective, or an adverb from the main clause (Diessel, 2004). This is a broad group of grammatical structures and includes temporal adverbials (e.g., "The plants grew after we watered them."), causal (e.g., "The plants grew because we watered them."), conditional (e.g., "The plants will grow if we water them."), concessive (e.g., "The plants did not grow even though we watered them."), and purposive clauses (e.g., "We watered the plants so that they would grow."). As with the other types of complex sentences, children exhibit early emergence and a long developmental trajectory for adverbial clauses. Note that children—even TD children—exhibit greater difficulty in comprehension of multiclause adverbials than may be expected on the basis of the early emergence of these structures (Bebout et al., 1980; French, 1988). Comprehension may be related to the specific connective used (e.g., "because," "unless"), the order of clauses (reflecting event order or reverse order), and the topic matter under discussion (de Ruiter et al., 2018; Donaldson et al., 2007). Child skill in comprehension of reverse-order adverbials (e.g., "She measured the plants after she trimmed them.") generally emerges later than comprehension of event-order adverbials (e.g., "She trimmed the plants before she measured them.").

Elementary School Science Instruction

If SLPs wish to understand the language demands of the science curriculum, at least basic knowledge of the nature of science instruction and expected student achievement standards is necessary. The Next Generation Science Standards (NGSS; NGSS Lead States, 2013) provide a comprehensive set of expectations for science achievement in children from kindergarten through 12th grade, targeting both the learning of essential concepts and the process of science. Although the NGSS include standards targeting specific conceptual knowledge, they also include skills related to the process of science that cut across broader content areas. For example, standards discuss children's ability to make claims about evidence, explain findings, and generate science questions—all of which are skills that are broadly applicable to multiple domains of science. Examine the following standard from third grade:

> 3-LS2-1 Ecosystems: Interactions, Energy, and Dynamics: Students who demonstrate understanding can construct an argument that some animals form groups that help members survive. (NGSS Lead States, 2013)

It is essential to note that children are required to "construct an argument" and not merely identify how

animals form groups. A key overarching goal of science instruction, as captured in the NGSS, is to teach children how to make claims about what may be a valid explanation of scientific phenomena and then to argue for those claims using evidence. This implies a level of engagement and understanding beyond regurgitation of facts and a level of language use that may be challenging for some children. The complexity of science learning goals requires the use of an array of instructional techniques. Ideally, children may gain scientific information through a combination of reading informational texts or trade books (Smolkin et al., 2009) and engaging in active experimentation and guided interpretation of results, as well as being provided examples and direct teaching from adults (Hushman & Marley, 2015).

Science learning is intended to build over time, such that skills built during early elementary school will support ongoing science learning later in the school years. For example, the target skill of "engaging in argument from evidence" that is targeted in the third-grade standard above continues to be addressed in standards from fourth grade through high school. The specific science content (e.g., ecosystems) varies over the grades, of course. However, the goal to build children's ability to argue for a claim using appropriate evidence remains, with specific expectations for child skill increasing over the years. This is a general pattern within science standards: Children are expected to learn both specific content for their grade level and to gradually build up the ability to engage in scientific processes like argumentation over development.

Language and Science

As illustrated in the discussion of science teaching above, science education is associated with specific types of language demands. The NGSS were first published in 2012, and the expectations they establish regarding skills such as explanation and argumentation do not reflect earlier approaches to science teaching. The demands on language in terms of science teaching likely include a higher frequency of use of complex sentences than other settings because of the reliance on certain types of talk. For example, expository discourse includes a higher rate of use of complex sentences than narrative or conversational discourse (Nippold et al., 2005). In terms of written language, researchers have argued for informational science text to provide more frequent explanations—and less frequent use of statements of facts and descriptions of scientific phenomena (Smolkin et al., 2009). However, the complexity of science texts is typically measured along several dimensions related to readability (e.g., use of advanced vocabulary), and thus, the rate of use of complex sentence structures within these books is not always clear (cf. Arya et al., 2017).

Current Research Note

Here, I investigate and describe the type of complex sentences presented to children within a general education science curriculum in elementary school, both in the context of expository text readings and suggested scripts provided to classroom teachers. My questions are the following:

1. How often are complex sentences presented within informational text from a general education science curriculum aimed at children at specific points (first, third, and fifth grades) during the elementary school years and what types of complex sentences are present?
2. How often are complex sentences presented within suggested scripts from a general education science curriculum provided to teachers at specific points (first, third, and fifth grades) during the elementary school years and what types of complex sentences are present?

Method

Approach

I reviewed curricular materials across three grades of interest in elementary school in order to determine the frequency and type of complex sentences used within each grade. I selected grades in order to analyze data from early elementary school (first grade), mid elementary school (third grade), and late elementary school (fifth grade) Results are presented descriptively for each grade level and type of material (texts/teacher scripts). Through review of both types of material, I am able to provide a comprehensive data set surrounding the grammatical structures provided by curriculum developers targeting children during these grades. Thus, this captures the language teachers are instructed to use verbally and to provide to students in written form.

Full Option Science System Curriculum

I reviewed all units from the first, third, and fifth grade levels of the NGSS edition of a popular general education science curriculum, the Full Option Science System (Lawrence Hall of Science, 2015). Each grade included one unit for physical science, one for life science, and one for earth science. Together, these units are intended to serve as the core materials for a full year of science instruction. Thus, this analysis demonstrates the language contained in the curriculum across a full school year for each year studied. The current edition of the FOSS is aligned with the NGSS, and each science unit includes a strong focus on active experimentation, along with an informational text containing multiple readings developed specifically for that unit. The content within the expository text aligns with the concepts discussed during the unit experiments. The suggested teacher scripts were obtained from a review of the *Investigations Guide* for each unit. The Investigations Guide serves as the teacher's manual and includes an overview of relevant science concepts, general teaching practices (e.g., suggestions for taking children outdoors during science teaching), and directions for each specific lesson. Within each lesson plan, there is suggested scripting provided to teachers for key concepts and questions. For example, teachers may be instructed to ask students

questions about experiments they are conducting or to provide definitions of new vocabulary terms. Although these procedures were specific to the design of the FOSS curriculum, similar methodology could be used with any commonly available science curriculum that provides both text for children to read and lesson plans for classroom teachers.

Transcription and Coding

Each sentence from the FOSS expository texts containing informational text for a specific reading (e.g., *The Story of Grain*) was transcribed, omitting glossaries and indices. Sentence breaks were placed where indicated by the text, and sentences presented in captions were included. Captions were included here because they are commonly used in science texts and may present relevant information within the text (Slough et al., 2010). Each sentence or student-directed question suggested for teacher use in the Investigations Guide was also transcribed. Teacher scripts were identified as passages that were explicitly marked as utterances teachers should direct to students, such as "Tell students, what I have here is a system…" (Lawrence Hall of Science, 2015, *Living Systems Investigations Guide,* p. 97). At some points in teacher scripts, teachers are provided with cloze sentences to use as prompts for students (e.g., "The bulbs that we planted are called ____."). However, text that was not directed toward students was not transcribed. This included instructions about preparation of materials and background knowledge of the science concept. Following transcription, each sentence was coded as *Not Complex, Complex,* or *Not Scorable.* Items coded as Complex were then coded as *Relative Clause, Complement Clause,* and/or *Complex Adverbial Clause.* Sentences with more than one type of subordination were coded and included in the totals for each type of subordination present. Cloze sentences were coded if the sentence type was unambiguous. Through combining these two sources of material, child texts and teacher scripts, we can determine the language demands the curriculum establishes both in written and spoken language. Items were regarded as Not Scorable if the sentence type could not be determined, which amounted to less than 3% of all sentences. Coordinated sentences were coded as Not Complex.

Reliability

Each sentence was coded as Complex, Not Complex, or Not Scorable by the author or one of three undergraduate student research assistants trained directly by the author. A minimum of the first 100 sentences per coder were recoded by the author to check that procedures were being correctly implemented and any discrepancies were being discussed. The coders actively consulted the author any time there was a question about coding.

Results

Expository Texts

Complex sentences were present in all three grade levels, with a range from 17.11% of all sentences in first-grade texts through 29.32% of all sentences in fifth-grade texts. Note that the increase primarily occurred between first- and third-grade texts, with little change in relative proportion of complex sentences from third to fifth grade texts. Complement clauses were the most frequent type of complex sentence evident in first-grade life sciences texts (7.57% of sentences). All three types of complex sentences were of similar frequency in third- and fifth-grade texts (see Figure 1).

Suggested Teacher Scripts

The pattern of results differed somewhat for suggested teacher scripts as compared to science texts. Note that the overall volume of sentences within teacher scripts differed across grades for teacher scripts: 395 for first grade, 1,102 for third grade, and 3,077 for fifth grade. As with the science texts, complex sentences of all types were noted across the grade levels. However, here, the range of complex sentences fell between 31.39% of sentences in first-grade scripts and 37.66% of sentences in third-grade scripts. There did not appear to be any gain in frequency of complex sentences between third- and fifth-grade scripts (33.05% sentences). Given the difference in volume of sentences across grades, fifth-grade scripts did include more complex sentences than third-grade scripts, despite the similarity in relative frequency. Of the three sentence types of interest, relative clauses appeared to be higher across each change in grade, ranging from 7.09% sentences in first-grade scripts to 10.75% sentences in fifth-grade scripts. Adverbial and complement clauses appeared relatively frequent in third-grade scripts, as compared to first- or fifth-grade scripts (see Figure 2). Within the first-grade Investigations Guide scripts, teachers were provided with explicit scripting regarding common grade-level safety requirements, such as "Do not put anything in your mouth."

Discussion

Findings indicate that general education science curriculum materials are designed such that they include use

Figure 1. Rate of complex sentences in science texts.

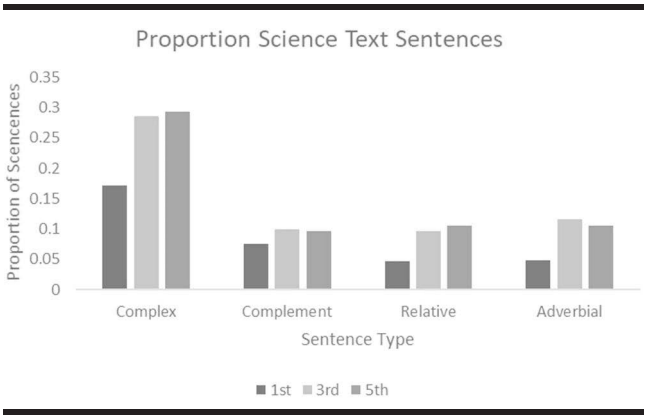
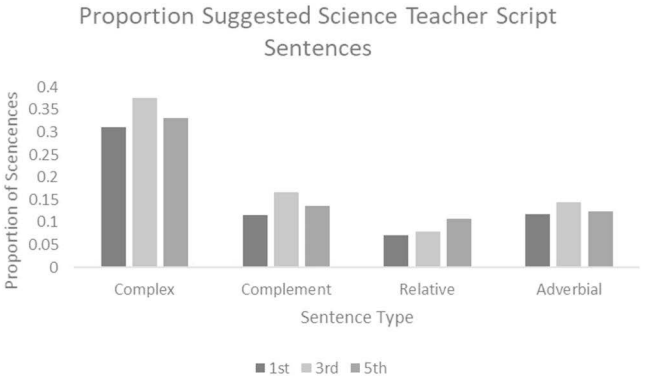


Figure 2. Rate of complex sentences in suggested teacher scripts.



of relative clauses, complement clauses, and adverbial clauses across first, third, and fifth grades, both in the texts children read and the language they hear from their teachers. Given that TD children produce complement clauses, relative clauses, and adverbial clauses by the time they enter kindergarten (Diessel, 2004), this may not pose an unreasonable level of difficulty for children with typical language skills. However, the speech that children produce—and hear in real-world settings—may differ from that presented in the FOSS materials. Given the presence of complex sentences throughout curricular materials across first, third, and fifth grades, there is reason for concern that children who do not yet readily comprehend or produce all of the complex sentence types under investigation may not be prepared for the language demands of the general education science setting.

Within the science texts, the relative rate of use of all complex sentence types, and of complex sentences overall, was higher in third and fifth grade than in first grade. In fact, by third grade, close to 30% of sentences in science texts involve some kind of complex syntax. However, SLPs working with children with language disorders may wish to keep in mind the fact that demands on complex sentence comprehension in science reading appear to increase during the first- to third-grade period. Thus, science texts are likely to pose challenges for children with poor complex sentence skills prior to late elementary school. This shift between first grade and third grade may reflect the expected rapid acquisition of reading skills by children in this age bracket. Note that, although the relative frequency of complex syntax does not increase between third and fifth grade, this does not indicate that expectations remain constant: There may be differences within sentence types that would be identified by a more fine-grained analysis (e.g., relative frequency of specific kinds of relative clauses). We already know from the literature that expository text may pose challenges for children along multiple dimensions (Mason & Hedin, 2011). Findings from this study indicate that frequent use of complex sentences in science text is another area of potential difficulty for children in elementary school.

The suggested teacher scripts and texts included a higher rate of complex sentences than the science texts in general. Across all three grades under investigation, complement clauses were relatively frequent, whereas adverbial and relative clauses were more frequent in third and fifth grade than in first grade. Recall that the scripts are intended to provide instruction regarding what to say at key points during a lesson, including providing instructions regarding class experiments, communicating concepts of interest, discussing new terms, and asking questions to elicit student responses. Teachers were prompted to use complex sentences to communicate specific concepts. For example, the fifth-grade Investigations Guide instructs teachers to say "Capillaries are tiny blood vessels that make contact with every cell in your body" (pp. 235). However, teacher scripts also appeared designed to target the type of overarching science learning skills that NGSS outlines as key to science learning. In other words, teachers are instructed to provide guiding questions and comments that prompt students to design experiments, make predictions, observe findings, and use evidence to back up a statement. For example, the third-grade Investigations Guide also prompts teachers to ask children the question "Do you think she will be able to get her hand out of the way when she sees the cup start to fall?" and then to reflect on why this may happen. Note that teacher scripts are not designed to outline everything a teacher says at every point during a science lesson. Additionally, teachers may choose to reword, omit, or add to key points in the script based on their own preferences or the needs of a particular classroom. Thus, additional research into the actual language used during live recordings of science teaching may add further insight into the frequency and types of complex sentences that children hear in science instruction during elementary school.

Recall that first-grade teacher scripts included behavioral instructions and that fifth grade was noted to contain a great deal more material overall than either of the other grades in the teacher scripts. These two trends may indicate changes in expectation both of children and of teachers across the grades. A considerable amount of the teacher talk directed toward young children involves behavior management, and thus, it is not surprising that suggestions regarding behavior management discussions should appear in science lesson plans. However, as with other behavior management language for young children, this is not likely to involve communication of science concepts with complex sentences. The notable shift between third and fifth grade in terms of teacher script length may reflect changes in child language and academic skill. However, it may also reflect the fact that early–mid elementary school teachers are typically generalists and focus the bulk of their time on literacy and mathematics (Rosenshine, 2015). However, by fifth grade, students may have teachers who have had additional training in science and are likely to have more class time for science learning than younger children. Thus, teachers of young children, who are focused on literacy and basic skills, receive scripts including behavior management, but of a briefer length than those for older grades.

Meanwhile, more specialized teachers with additional instructional time for children who are potentially more capable (due to their age) receive a greater intensity of teacher scripting focused on science concepts.

SLPs and researchers can leverage the findings of this study to advance evidence-based practice for elementary school students. SLPs working in the schools can leverage the findings of this study to facilitate curriculum-relevant intervention planning for children in elementary school. In examining the types of sentences used at different grades, SLPs can learn what student skills may be necessary to meet the likely language demands of the classroom. They may then be able to identify potential treatment targets that are frequently found in science instruction. SLPs may use these findings when consulting with general education teachers regarding the language supports and needs of children in the classroom. After all, a general education science curriculum may prompt teachers to use complex sentences during instruction, even in first grade, and an SLP could provide information to teachers about how to support child success or what potential areas of difficulty may arise.

Once SLPs have identified complex sentence types that frequently occur in science instruction, they must also identify how best to treat these sentences. There is an emerging literature surrounding complex syntax intervention (see Weil & Schuele, 2019, for an overview), though the evidence base here is not yet as strong as it may be for other grammar intervention targets, such as tense and agreement markers. We now know that complex sentences are frequent throughout the course of science instruction in the elementary school grades, indicating that this may be a fruitful area for intervention research. However, we do not yet know how best to treat these types of complex sentences in children across this age range. Thus, the results here also serve as evidence that additional research into this area is warranted.

Limitations

This discussion concerned one specific curriculum and thus may not generalize to all science curricular material, particularly from curricula that are not explicitly aligned with NGSS. In combination with the expository texts, suggested teacher scripts allow us to analyze the grammatical structures curriculum developers aim to include at each grade level. However, these scripts do not provide live teacher talk measures, which may affect the rate and type of complex sentences observed. With that said, use of the materials included here provides a complete set of data regarding the type of language curriculum developers provide for use with children in these grades. Finally, more fine-grained coding of the data here could provide additional insight into the specific subtypes of complex sentences present in the curriculum (e.g., nonfinite vs. finite complement clauses). However, as a first step, this study allows us to examine the overall prevalence of each major type of complex sentence and identify areas for further in-depth investigation in the future.

Conclusions

This research note illustrated the ways in which a popular general education science curriculum uses complex sentences to communicate key concepts throughout the elementary school years, both in the text children are expected to read and in the verbal language teachers are instructed to use. SLPs should be aware that elementary school students encounter complex sentences in science instruction in grades throughout elementary school, including first, third, and fifth grade. Children are expected to engage with concepts presented in complex sentences containing adverbial clauses, relative clauses, and complement clauses both in expository text passages and in teacher talk during science lessons. SLPs should take this into account when identifying potential treatment targets to support curriculum-relevant language skills and may work on comprehension of these sentences or consultation with general education teachers who provide science instruction. Demands on complex sentence skill may increase between first and third grade. Further work is necessary to clarify evidence-based methods for treatment of complex sentences at these grades and the effect of such intervention on child outcomes.

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