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Teaching text structure in science education: What opportunities do textbooks offer?

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Abstract A body of research has shown the merits of text structure instruction and advocates the integration of reading instruction in content learning. In view of the Component Model of Reading, which underscores the importance of ecological components such as textbook content, we conducted a materials analysis of seven Dutch science teaching programs developed for grades 3–6, to examine to what extent these materials are appropriate for text structure instruction. Results show that the materials do offer opportunities for text structure instruction but are not suitable for a step-by-step implementation and practice of knowledge and skills related to text structure. Textbooks offer too few clear organized single-structured texts, and not all text structures are sufficiently represented. Programs differ strongly in text length, segmentation and use of introductions. Illustrations and assignments hardly connect to the text structure. These results call for design-based research to develop materials that foster literacy via science education.

Keywords text structure instruction, science textbooks, primary education, corpus-based analysis

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None

Supporting information
Appendix A – Examples from the teaching materials analyzed. Appendix B – Clarification and examples of the analysis of assignments per text structure. Appendix C – Inter-annotator agreement (Cohen's kappa and % agreement) per feature coded. Appendix D – Results from the statistical analyses. Appendix E – Two versions of a paragraph about fossil fuels

1 Introduction

Over the last two decades, outcomes of the Progress in International Reading Literacy Studies conducted in primary education (PIRLS; Gubbels et al., 2017) have shown a stable level of reading proficiency of Dutch fourth graders. National assessments of reading comprehension conducted in third and sixth grade in 2005 and 2011 show a comparable stable reading proficiency (Kühlemeier et al., 2014). Nevertheless, between 2001 and 2016,

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the Netherlands dropped in ranking from the second to the fourteenth position due to the fact that other countries performed better (Gubbels et al., 2017).

A closer look at the Dutch results of PIRLS 2016 reveals two other striking outcomes. The first is that only one third of the Dutch children felt engaged during reading lessons, against an international average of fifty percent of the children. The second is that scores for tasks that demand interpretation, integration and evaluation of ideas and information declined between 2001 and 2016, whereas all other countries, except France, showed an increase on these tasks, or remained stable (Gubbels et al., 2017).

As reading skills are essential for school success and participation in our literacy-oriented society (Mol & Bus, 2011; Murnane et al., 2012), these findings are alarming and underpin the need to examine how reading education in Dutch primary schools can be strengthened. Fortunately, international reading research has generated extensive knowledge about the reading process and the characteristics of effective reading instruction (see for an overview Duke et al., 2021). For instance, vocabulary and knowledge building, comprehension strategy instruction, discussion about texts, combining reading and writing, and fostering reading interest (through, for example, hands-on activities) are among the recommended approaches (see also Pearson et al., 2020). Another approach that has been shown to improve reading proficiency is text structure instruction (Bogaerds-Hazenberg et al., 2020; Hebert et al., 2016; Pyle et al., 2017). However, current educational practices in the Netherlands reveal a research-practice gap: evidence-based effective reading pedagogies are still insufficiently implemented in Dutch classrooms (Pereira & Nicolaas, 2019).

Although we acknowledge the potential of investing in other aspects of reading instruction as well, this study focuses on two evidence-based recommendations that seem to be particularly neglected in Dutch primary education: 1) embed reading instruction in content learning (Wigfield et al., 2016), and 2) teach children about text structures (Duke et al., 2021). In Section 1.1 and 1.2 we will elaborate on these approaches and substantiate their relevance for improving reading motivation and text comprehension. In Section 1.3 we will clarify why science education seems particularly suitable for text structure instruction and explicate the purpose and research question of our study.

1.1 Reading instruction in content learning

As mentioned before, both national and international research on reading education display Dutch students' lack of engagement in reading instruction. One of the explanations for this lack of motivation can be found in the way reading education is conducted in Dutch primary education. A typical feature of Dutch reading instruction is the strong focus on strategy instruction. This focus is in fact so strong that practicing the application of strategies while answering questions about a text has become the main purpose of reading lessons (Bogaerds-Hazenberg et al., 2022). As a consequence, reading tasks hardly promote a transfer of reading skills to other subjects, and do not appeal to a sense of autonomy and engagement in children, which results in a lack of motivation (Aarnoutse, 2017).

Reading motivation is determined by many factors, including reader, task and text characteristics, and it has also been established that reading motivation and text comprehension are reciprocally related (Toste et al., 2020). Therefore, it is important to choose a reading instruction policy that supports motivation (Houtveen et al., 2019). One of the instructional practices that have proven to enhance both children's reading motivation and text comprehension, is the integration of reading instruction in content-area subjects. In such practices, knowledge acquired through content-area instruction can be viewed as both a foundation and a motive for reading (Cervetti et al., 2012). In curricula integrating literacy and content learning, language education is often integrated in science. This makes sense as scientific inquiry learning provides a meaningful context for reading, and reading can help students construct their understanding of science concepts (Bradbury, 2014). Texts can thus support scientific inquiry in broadening and outlining what is learned in firsthand investigation and, in addition, science and literacy share meaning-making strategies such as metacognitive regulation and making connections (Cervetti et al., 2005). Intervention programs that integrate science and language arts at the elementary level have shown positive effects on both science knowledge and language proficiency as measured via reading assessments and writing tasks. On top of that, integrated approaches facilitate improved attitudes toward both reading and science (Bradbury, 2014). Despite these benefits, an integrative approach of science and literacy is rarely practiced in the Dutch context of primary education (Gresnigt, 2018).

1.2 Text structure and text comprehension

A closer look at the results of PIRLS 2016 but also at the outcomes of assessments of reading proficiency conducted at the national level, reveals that reading tasks appear to be particularly difficult when texts are complex, and students have to make inferences within and beyond the text, make multiple inferences, or summarize and connect text parts beyond the sentence level (Gubbels et al., 2017; Kühlemeier et al., 2014). These outcomes indicate that Dutch children in primary education struggle particularly with higher-order reading skills.

In order to tackle this problem, and learn children how to build a coherent mental representation of the macrostructure of a text, it has been recommended to provide text structure instruction (Bogaerds-Hazenberg et al., 2020; Hebert et al., 2016; Pyle et al., 2017). Text structure concerns the way in which the ideas in a text are organized and related (Pyle et al., 2017, p. 469); it plays a prominent role in the representation that readers make of the information in a text. A clear text structure makes it easier to construct a coherent representation (Sanders & Sanders, 2006). Coherence relations between parts of a text can be found at three levels: between clauses, between sentences, and between larger text parts such as paragraphs, the so called top-level structure of the text (Jones et al., 2016). In other words, coherence relations like *cause-consequence* and *list* do not just exist between consecutive sentences; they can also constitute text structures that organize whole paragraphs or texts (Sanders et al., 1992). The five most common text structures in expository texts are: description, sequence, cause-and-effect, compare-and-contrast, and problem-and-solution (Meyer, 1975). Appendix A shows short descriptions and examples of each of these text structures.[1]

How knowledge about text structure can facilitate text comprehension during the reading process can be explained using the Construction-Integration Model of text comprehension (Kintsch, 2013). This model pictures reading as an interactive process of construction and integration, involving the activation of prior knowledge and making inferences within and beyond the text in order to form a coherent mental representation of the text: the situation model (van Dijk & Kintsch, 1983; Pyle et al., 2017). The five text structures listed in Appendix A can thus be seen as prototypical rhetorical structures consisting of specific coherence relations (Graesser et al., 2004). Good readers use the so-called structure strategy, which means that they use the organization of ideas in a text to organize their own understanding. Markers of text structure such as signaling words can cue text structures and help readers build a coherent text representation (Meyer & Ray, 2011; Sanders et al., 2007; Sanders & Noordman, 2000; van Silfhout et al., 2015).

Text structure instruction can improve reading comprehension in a number of ways. With knowledge about text structures it is easier to predict what the text will be about and to locate certain information in the text. Understanding how the author presents and organizes information can free up memory and processing resources and allows the reader to focus on the content of the text. It also promotes deciding which information is important, and facilitates the process of creating a coherent mental representation (Hebert et al., 2016; Pyle et al., 2017). Several meta-analyses have indeed shown positive effects of text structure instruction on text comprehension of both narrative and expository texts, even in young children (Bogaerds-Hazenberg et al., 2020; Hebert et al., 2016; Pyle et al., 2017).

Nevertheless, text structure instruction currently receives little attention in Dutch primary education. Activities aimed at text structure are often spent on recognizing signaling words, but hardly any connection is being made between signaling words and the type of inferences they mark, neither is it explained how signaling words can facilitate the reading process. Furthermore, analyses of reading instruction materials reveal that declarative knowledge taught about various text structures is scant and in some reading programs even limited to the classification of *introduction, core* and *conclusion* (Bogaerds-Hazenberg et al., 2017, 2022).

Taking into account the large body of positive effects of text structure instruction on text comprehension, and considering the outcome that Dutch students particularly seem to struggle with reading tasks that require text comprehension at the level of the situation model, expanding and improving text structure instruction in Dutch primary education seems a favorable approach.

1.3 Science education and text structure instruction

Given the finding that the combination of literacy and science education benefits reading proficiency, it is worthwhile to examine if and how text structure education can also be integrated in science education.[2] In addition to the aforementioned opportunities, this approach seems promising because expository text structures appear to match science content very well. Text structure instruction focuses on coherence relations such as *sequence* and *cause-effect*, whereas science education teaches crosscutting concepts such as *systems* and *cause and effect* (Duschl, 2012). Text structure can thus be deployed to explicate these crosscutting concepts and thereby promote both text comprehension and comprehension of the content being taught.

However, before considering any implementation of evidence-based recommendations for reading instruction, it is important to understand what is already being taught in schools and to learn more about the texts, illustrations and assignments in the textbooks (Wijekumar et al., 2021). The content and quality of textbooks is an ecological component of relevance in the Component Model of Reading proposed by Aaron et al. (2008). Reviews of textbooks in several countries have already shown that evidence-based practices are hardly implemented in textbooks, and that assignments do not promote higher-order thinking skills (Agius & Zammit, 2021; Peti-Stantić et al., 2021). Since little is known about the content of Dutch science teaching materials and the opportunities for text structure instruction in particular, we conducted an analysis of textbooks created for grades 3 to 6. These materials were included in the corpus because students make the transition from 'learning to read' to 'reading to learn' starting from grade 3 (Fang, 2008), and several studies indicate that text structure instruction should be taught from an early grade level, with a steady increase in text complexity over grade levels (Pyle et al., 2017; Williams et al., 2014). The aim of our analysis was to answer the following research question:

To what extent are current Dutch science textbooks and workbooks used in grades 3–6 appropriate for text structure instruction?

To gain insight into the variety of the teaching materials available, we examined whether and how the science programs differed on the features we analyzed. In order to find out whether the materials show an increase in complexity, we also compared the outcomes of grades 3/4 and grades 5/6. We consider this analysis a case study that could inform researchers and educational experts from other countries as well about the opportunities that can be found for text structure instruction in which science teaching materials are used.

2 Texts and assignments required for text structure instruction

Looking at the kinds of texts and assignments used in previous text structure interventions, we can derive a set of material characteristics that have shown to be beneficial for improving text comprehension. First and foremost, teachers should have access to a wide range of texts that can be used for modeling and scaffolding. Therefore, Section 2.1 describes the text features required for effective text structure instruction. In Section 2.2, we explicate the usefulness of visualizations of the text's structure, and in Section 2.3 we consider three important assignments often used in text structure instruction: 1) summarization tasks such as filling out graphic organizers, 2) inference questions, and 3) writing tasks.

2.1 Texts

In order to be able to learn how to apply text structure knowledge during reading, students need instruction about text structures such as comparison, cause-effect and problem-solution (Ray & Meyer, 2011). Although it is unclear in what order the different structures should be introduced and if some combinations of text structures are more effective than others, research indicates that it is useful to teach multiple structures concurrently (Bogaerds-Hazenberg, et al., 2020; Hebert et al., 2016). For the introduction of a new text structure, readers need exemplary, well organized single-structured texts as model texts (Jones et al., 2016). Once readers are familiar with several text structures, they should be familiarized with reading multiple structured texts, shaping up to the ability to attend to the complexity of text structures in authentic texts (Dickson, 1999; Jones et al., 2016; Pyle et al., 2017).

Readers' ability to recognize and use text structure can also be positively influenced by textual signaling devices that explicitly indicate the structure of the text (Ray & Meyer, 2011). Text features such as titles, headings, introduction and conclusion, segmenting and graphical features are organizational features that can help students to identify the structure of a text. Texts being used in text structure instruction should therefore provide clear examples of these features (Jones et al., 2016; Ray & Meyer, 2011). This starts with a well-articulated layout that guides the learners through the resources and enables them to easily identify relevant information (LaSpina, 1998; Pettersson, 2015). Previous research has revealed that in many content-area textbooks it is hard to identify the organizational principles at the global and local level (Armbruster & Anderson, 1988), even though educational publishers have ample opportunity to use page layout, paragraphing and graphic aids to highlight the structure of the texts.

Figure 1 and 2 show two examples of science texts for primary education. In Figure 1, segmenting and layout are clear, whereas Figure 2 displays a colorful and scattered layout with a variety of font types and sizes, which make it hard to find out the reading direction and the hierarchy between text parts.

thema 2 – Oerkrachten van de aarde

les 4 – Stuiterbalonderzoek

Hoe word je een echte wetenschapper?

Hoe weten we dat de aarde leeft? Dat weten we dankzij wetenschappers. Wetenschappers stellen vragen en zoeken daarna zelf naar de antwoorden. Die zoektocht is het onderzoek. Het onderzoek in deze les gaat over stuiterballen.

1

Spelregels van de wetenschap

Wetenschappers zijn nieuwsgierig. Ze willen álles weten. Wat is de waterkringloop? Hoe werkt een vulkaan? Hoe komt het dat geisers water omhoog spuiten? Sommige vragen zijn dichter bij huis. Het krantenbericht gaat over een proef met licht in de klas. De onderzoekers ontdekten iets heel leuks. Kinderen kunnen beter leren als het licht een beetje blauw is. Goed om te weten! Je kunt alles onderzoeken. Toch is één ding altijd hetzelfde: de spelregels. Wetenschappers doen onderzoek in zes stappen.

een nieuwsbericht over het lichtonderzoek in de klas

2

Stap 1 Bedenk een vraag

Je bent net begonnen als wetenschapper. Dan ga je geen saaie dingen onderzoeken. We beginnen met iets leuks. Een onderzoek naar … stuiterballen! Of eigenlijk: naar ballen die stuiteren. Een pingpongbal, een tennisbal, een golfbal en een voetbal. Wetenschappers moeten heel precies zijn. Ze kunnen niet zomaar iets opschrijven. Het onderzoek krijgt daarom een echte titel: Onderzoek naar het stuitergedrag van verschillende soorten ballen. De vraag van het onderzoek is: Welke bal stuitert het hoogst?

Sommige ballen stuiteren wel heel erg goed …

3

Stap 2 Doe een voorspelling

Jonge onderzoekers willen natuurlijk snel aan de slag. Maar wacht even! Echte wetenschappers slaan geen stap over. Stap 2 is de voorspelling. Voordat je begint, moet je even nadenken. Wat denk je dat er uit het onderzoek komt? Stuitert de golfbal het hoogst of de pingpongbal? En wat doet de tennisbal? De voorspelling is heel belangrijk. Misschien komt de voorspelling uit. Dan wist je dus precies wat er ging gebeuren. Komt de voorspelling niet uit? Dan leer je iets nieuws. Nieuwe dingen ontdekken. Dat doen wetenschappers het liefst …

Een wetenschapper probeert de uitkomst te voorspellen.

4

Stap 3 Maak een plan

Wetenschappers spelen niet vals. Een onderzoek moet eerlijk zijn. Daarom maken onderzoekers eerst een plan. Het onderzoek naar de ballen moet ook eerlijk zijn.

Eerlijk is: Alle ballen van dezelfde hoogte laten vallen.
Oneerlijk is: De ene bal van een meter hoog, de andere van het dak.
Eerlijk is: Alle ballen op dezelfde ondergrond laten stuiteren.
Oneerlijk is: De ene bal op vloerbedekking, de andere op zeil.
Eerlijk is: De ballen rustig loslaten.
Oneerlijk is: De ballen een extra zetje geven.

Wat ga je doen om de vraag uit stap 1 te beantwoorden? Dat schrijf je op in het plan.

Vals spelen is er als wetenschapper niet bij!

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Figure 1 Science text with a clear layout (*Argus Clou*, grade 5, pp. 38–39, printed with permission)

THEMA 8.3 LES 1
Goeie vraag!

VRAAG MAAR RAAK!

Waarom is de zee zout? Waarom moet je eigenlijk je tanden poetsen? Hebben koninginnen echt blauw bloed? Vallen boterhammen altijd met de pindakaas-kant op de grond? Wat zoeken mensen toch in de ruimte? Hoe kun je het beste die chocoladefiguurtjes uit de hagelslag naar boven krijgen? Waarom dragen nette mannen stropdassen? En waarom, waarom toch, zijn de bananen krom?

Vind je dit gekke vragen? Dan zul je nooit een goede wetenschapper worden. Want een goed onderzoek begint met een vraag. Meestal zijn kinderen juist goed in vragen stellen. Ze vragen hun ouders soms de oren van de kop. En dat is geweldig, want zo ontdek je steeds meer over hoe de wereld in elkaar zit.

Je moet nooit stoppen met vragen stellen. Want door veel te vragen word je alsmaar slimmer. Volwassenen doen soms alsof ze alles begrijpen. Maar die durven gewoon niet te laten merken dat ze iets niet weten. En daar schiet je natuurlijk niets mee op.

Er zijn ook volwassenen die van vragen stellen hun werk hebben gemaakt. Wetenschappers die proberen op elke vraag een antwoord te ontdekken. Ze onderzoeken, experimenteren en denken na. En dan verzinnen ze weer nieuwe vragen.

SOORTEN WETENSCHAPPERS

Wetenschappers komen voor in verschillende soorten. Ze hebben allemaal zo hun wereldje waarin ze werken. Bijvoorbeeld:

- Astronomen onderzoeken sterren, planeten en alles in het heelal.
- Biologen onderzoeken planten, dieren en bacteriën.
- Geologen onderzoeken de aarde.
- Scheikundigen onderzoeken hoe stoffen reageren.
- Natuurkundigen onderzoeken verschijnselen die je kunt waarnemen en meten (bijvoorbeeld energie, licht, geluid of magnetisme).

PROEFJES IN JE EIGEN KEUKEN

Iets onderzoeken hoeft niet per se in een laboratorium. Het kan ook gewoon in je eigen huis, met alledaagse spullen. Zo vond de Fransman Arthur Goot het leuk om allerlei onderzoekjes te doen samen met zijn zoon Jan. Daarvoor gebruikten ze kurken, lucifers en keukengereedschap. Ook deden ze graag proefjes met eieren. Bijvoorbeeld deze:

Leg een gekookt ei zonder schil op de opening van een glazen fles. Het kan er nét niet doorheen. Maar doe een brandende lucifer in de fles en het ei wordt er toch ingezogen. Dat komt omdat de luchtdruk in de fles lager wordt als de lucifer uitgaat. De luchtdruk aan de buitenkant van de fles zorgt ervoor dat het ei door de opening wordt geduwd.

Hoe kun je ontdekken of een ei dat in de koelkast ligt rauw is of gekookt? Daarvoor moet je ze laten draaien. Geef het ei een slinger en stop het draaien dan door het ei even kort aan te raken. Laat los en kijk of het ei nog doordraait. Is dat zo, dan is het ei rauw. Een gekookt ei ligt meteen stil. Dit komt doordat de vloeibare inhoud van een rauw ei nog even doordraait.

Deze onderzoekster geeft de jonge en volwassen stokstaartjes een eigen merkteken. Zo kan ze de stokstaartjes volgen en observeren.

LEVENLOZE NATUUR

Natuurkunde is de wetenschap die alle verschijnselen in de levenloze natuur onderzoekt. Bijvoorbeeld geluid, licht, kleur, warmte, lucht, magnetisme, (statische) elektriciteit, vaste stoffen en vloeistoffen. Al die natuurkundige verschijnselen hebben hun eigen kenmerken.

Met natuurkundige verschijnselen kun je experimenteren. Natuurkundige wetenschappers doen dat. Ze willen namelijk weten hoe dingen werken en waarom. Ze stellen zichzelf allerlei vragen en doen proefjes. Tijdens het experimenteren met elektriciteit ontdekten natuurkundigen bijvoorbeeld dat niet alle materialen hetzelfde reageren op stroom. Sommige materialen laten stroom door. Die noemen we geleiders. Andere materialen houden stroom tegen. Die noemen we isolatoren. Daardoor weten we hoe je een stroomkring kunt onderbreken. Handig, want zo krijg je geen elektrische schok als je een snoertje aanraakt. Er zit plastic om. Elektriciteit kan alleen maar stromen als de stroomkring gesloten is. Het plastic zorgt ervoor dat er tussen jou en de stroomdraad geen stroomkring ontstaat.

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Figure 2 Science text with a scattered layout (*Blink Wereld*, grade 6, unit 8.3, lesson 1, printed with permission)

Introductions to the text can foreshadow the content and provide information about the text organization (Lorch & Lorch, 1996; Ray & Meyer, 2011). For instance, example (1) mentions the main topics of the text and provides insight into the text structure. Based on this introduction, the reader can expect cause-effect relations and a problem-solution structure. By contrast, example (2) only introduces a topic, probably to draw attention to the reader, but hardly refers to the content and structure of the text, which describes geothermal energy and the way this is being used for heating.

(1) This lesson is about how people have a big impact on the environment. You will learn about the consequences of catching too many fish and using toxic substances in agriculture. You also learn how people can change the climate (*Wijzer*, grade 6, p. 58).

(2) Earth is a special place. On the Japanese island of Honshu, for example, it gets quite cold in winter. Minus 20 degrees Celsius in the mountains. But there are also springs with hot water over there. Really hot, 40 to 60 degrees Celsius (*Blink Wereld*, grade 4, unit 6.2, lesson 1)

Given the importance of the text features mentioned above, our materials analysis will include an analysis of a) the text structures found in science books, b) the layout of these texts, and c) the presence and content of introductory paragraphs.

2.2 Illustrations

Over time the number of images and graphical resources in science textbooks has increased significantly. Where language predominated traditional textbooks, modern textbooks are often organized around images. This shift in the proportion of text and images caused a change in the relationship between written texts and images. In traditional textbooks, illustrations were subordinate to the text, whereas in modern texts the combination of text and image serves functions of complementation, comparison, contrast, detail or elaboration. Images can, for example, be used as rhetorical devices and thereby relate to larger patterns of text organization (Martins, 2002; Mayer, 2009; Mikk, 2000).

Pictures can enrich or elaborate the representation of the text. In some cases the picture represents the structure of the text and can thus support the formation of the mental model (Eitel et al., 2013; Schnotz et al., 2014). Figure 3 for example can help the reader to follow the sequential steps mentioned in the accompanying text. Psycholinguistic studies have revealed the multimedia effect, establishing that knowledge acquisition through a combination of visuals and text is more successful than through text or images in isolation (Clark & Mayer, 2016; Mayer, 2009; Serafini, 2022). Thus, illustrations that visualize the rhetorical structure of the text can be a useful tool in text structure instruc-

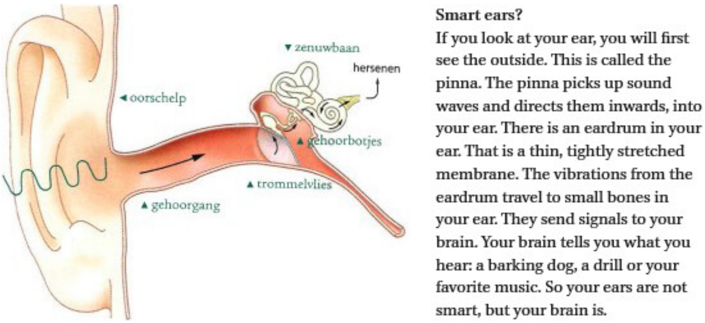

Figure 3 Example of an illustration that pictures a sequence described in the text (*Naut*, grade 4, p. 19, printed with permission)

tion, which is why we analyzed the presence of such illustrations in Dutch books for science education.

2.3 Assignments

In learning to recognize the structure of a text and to use it for text comprehension, students may benefit from reading comprehension activities such as summarizing, generating inferences, and monitoring comprehension (Wijekumar et al., 2017). Asking targeted questions about the text structure in order to select the most important elements in the text has proven to be an effective strategy in scaffolding (Williams, 2018). This can for instance be done with inference questions such as (3) or sentence-completion tasks such as (4).

(3) Why do so many plants grow in the tropical rainforest? (*Naut*, grade 5, p. 9)

(4) The earth is getting warmer.
Enter the right word.
_________fuels emerged millions of years ago. In the combustion of coal, oil and natural gas _________comes free. That fades in the _________ As a result, more _________is being held on earth. This is called the _________ greenhouse effect. As a result, the _________ on earth changes very slowly. (*Wijzer*, grade 6, p. 61)

Another powerful tool to help students develop schemata for specific text structures and to comprehend and recall information from texts, is the use of structure-based visualizations, so-called graphic organizers (Bogaerds-Hazenberg et al., 2020; Pyle et al., 2017). It is important that students not only are exposed to these visualizations, but also actively fill out graphic organizers (Bogaerds-Hazenberg et al., 2020). In the *Natuurzaken* materials for grade 4, for instance, we found a text about the life stages of a human being.

Table 1 List of the seven science programs analyzed

Program	Publisher	Year of publication
Alles-in-1 (A1)	De bloeiende naboom	2013
Argus Clou (AC)	Malmberg	2012
Blink Wereld (BW)	Blink	2017
Natuniek (Nn)	Thieme Meulenhoff	2007
Natuurzaken (Nz)	Zwijsen	2013
Naut (Nt)	Malmberg	2008
Wijzer (W)	Noordhoff Uitgevers	2015

In the accompanying assignment, students are asked to connect the concepts 'toddler', 'adolescent', 'baby' etc. to a timeline and, by doing so, become aware of the sequential order of the ideas in the text.

Several scientists have emphasized the importance of including writing as a part of text structure instruction (Hebert et al., 2016; Ray & Meyer, 2011). Again, such writing activities can draw students' attention to the structure of the text. In our materials analysis, we examined the assignments to find out whether these can be related to the structure of the text.

3 Method

We conducted a materials analysis of Dutch science programs for primary education. In this section, we clarify our methodological considerations, discussing the selection of materials in Section 3.1, the method of analysis in Section 3.2, inter-annotator agreement scores in Section 3.3, and the method for statistical analysis in Section 3.4.

3.1 Material selection

We selected five science programs produced by the four largest educational publishers for primary education in the Netherlands (Malmberg, Thieme Meulenhoff, Zwijsen and Noordhoff Uitgevers), and added two science programs that apply an innovative approach: *Alles-in-1* is a thematically organized teaching program that integrates the content subjects with language arts. *Blink Wereld* takes inquiry learning as a starting point (see Table 1). For each program, we randomly selected the textbook and workbook materials of three teaching units per grade. Consequently, for every program twelve teaching units were analyzed, resulting in a corpus of 84 teaching units.

3.2 Method of analysis

We coded features of the texts and of illustrations in the textbooks, as well as features of the assignments in the workbooks. This section explicates how the analysis was conducted.

3.2.1 *Text segmentation and text length*

A first glance at the textbooks made clear that the selected science programs displayed a large variety in text length, amount of text, degree of segmentation and type of lay-out. These differences might interfere with the number of text structures found in the textbooks, simply because longer texts offer more space to include multiple text structures. In order to take this into account and to be able to code certain features per text or paragraph, we first determined the size and the degree of segmentation of the text corpus. In our definition of what could be considered as one text we decided to align with the way publishers presented consecutive texts: parts of the teaching unit were considered as one text if they consisted of one or more paragraphs with one or more subheadings. A new text started with each distinct topic change or main shift in lay-out. A paragraph was defined as a text unit with a heading or a subheading. Introductions also counted as one paragraph. Text parts with fun facts, lists of definitions, repetitions of learning goals, personal stories of experts and summaries were excluded from this analysis. Subsequently we counted the number of texts per unit, the number of paragraphs per text as well as the number of words and number of sentences per paragraph.

3.2.2 *Coherence relations and text structure*

Text structure instruction interventions aimed at expository reading comprehension most often target the more organized structures, such as compare-contrast en cause-effect (Hebert et al., 2016). A descriptive text structure displays the least sophisticated level of organization as it often results in a list of ideas instead of a hierarchal structure (Jones et al., 2016). We therefore excluded the descriptive structure from our analysis.

To account for the large differences in segmentation and text length between science programs, and because we wanted to do justice to the presence of structures in parts of instead of the entire text, we followed a two-step approach in the coding of both paragraphs and texts. At the paragraph level, we first coded all coherence relations between sentences within a paragraph. As a consequence of this decision one paragraph could contain more than one coherence relation or structure. Second, we determined the top-level structure of every paragraph that was assigned to one or more of the four text structures under investigation. In (5) for example, only the second part of the passage describes a relation of cause and effect. Since this text part covers two sentences, it is still coded as a paragraph with a cause-effect structure. By contrast, example (6) subsequently contains relations of problem-solution, sequence and cause-effect and was

Table 2 Criteria for coding text structures

Text structure	Criteria
Sequence	– The text describes actions or events that use to happen or have happened in a sequential order – At least three steps of a sequence can be distinguished – The sequence does not have to be found in adjacent sentences but can for example be interspersed with descriptive sentences
Cause-effect	– The text describes a relation of cause and effect – The sequence can either be cause-effect or effect-cause
Problem-solution	– The text describes a problem and one or more solutions – The sequence can either be problem-solution or solution-problem
Comparison	– In the text two or more topics are compared – The text describes at least one similarity and one difference between the topics compared

therefore assigned to three structures at the paragraph level. Still, in this passage, the problem-solution structure can be considered the top-level structure of this paragraph.

(5) *Tropical wood*
Bankirai, Teak, Merbau, Meranti, Mahogany, Wenge. More and more often you can come across these names in brochures from hardware stores and furniture stores. They are all names of tropical wood: types of wood that come from tropical rainforests. These are forests that lie around the equator. **Wood from the tropical rainforests is very popular. This is because this wood suffers less from moisture and fungi than wood from other areas.** (*Naut*, grade 5, p. 12)

(6) *See with your ears*
Dolphins cannot see well under water. Therefore, when hunting prey, they use their hearing. A dolphin makes high-pitched sounds under water. These sounds bump into its prey. The sound reverses and returns to the dolphin. The reversal of sound is called an echo. Through that ultrasound, a dolphin discovers where its prey is. A dolphin 'sees' its prey with its ears. (*Natuniek*, grade 3, p. 46)

The more specific criteria for analysis at the paragraph level are listed in Table 2.

For the text structure analysis at the text level, we applied a similar approach, using the same definitions as we did at the paragraph level. In our first round of analysis a coherence relation was coded if it exceeded at least two adjacent paragraphs. Given the fact that the number of paragraphs in the texts differed from one up to sixteen paragraphs, in some cases two or more different structures were coded for one text. For example, two adjacent paragraphs could contain a sequence while two other paragraphs in the same text could show a structure of cause-and-effect. Subsequently, we also determined the top-level structure of the text as a whole.

3.2.3 *Layout, introductions and illustrations*

Layout and text segmentation can help the reader figure out the underlying structure of a text. Therefore, we coded for every text whether the layout was well-articulated and offered the reader a clear impression of the reading direction and hierarchy in the text (see Figure 1), or whether the layout was rather scattered, as in Figure 2 in Section 2.1.

Introductions to a text can help the reader predict the content of the text and gain insight into the structure of the text. Therefore, we analyzed whether a text started with an introduction and, if so, whether this introduction served as an advance organizer to the content of the text. Paragraphs at the beginning of a text and standing out in terms of layout, font or color were coded as an introduction to the text. Paragraphs describing learning goals at the beginning of the text were only included when presented in running text, and not for instance in a bulleted list. Per introduction we coded whether the content could be used as an advance organizer (see (1) as an example) or not. Advance organizing could be done by listing the contents of the text, using a guiding question, or by means of a short preview. If an introduction only served to attract the reader's attention or did not provide enough information to picture the content of the text, as in example (2), it was not coded as an advance organizer.

For every paragraph that contained one of the four text structures, we examined whether the content of the structure was visualized in one or more illustrations accompanying the text. Figure 3 in Section 2.2 shows an example of an illustration that reflects the relations conveyed in the structure of the paragraph.

3.2.4 *Assignments*

All assignments were examined to determine whether they could be related to one of the rhetorical structures: sequence, cause-effect, comparison and problem-solution. If an assignment was related to one of these structures, we also analyzed whether the required information could be found in the text. In addition, we checked whether the structure of the assignment matched the structure of the information provided in the textbook. An assignment could, for example, ask students to put several events in the right sequence, and the accompanying text could also be a text with a sequential structure or not. A detailed description of how we analyzed the assignments and examples from the corpus is included in Appendix B.

3.3 Inter-annotator agreement

In order to test whether the coding protocol resulted in consistent categorizations of the content being analyzed 10 % of the corpus was coded by a second annotator (Lacy et al., 2015; cf. Neuendorff 2002). This was conducted in four stages: 1) texts, 2) paragraphs, 3) illustrations and 4) assignments. During each stage the second annotator first engaged in a training phase to make her familiar with the procedure and criteria in the codebook. After this training phase the outcomes and differences were discussed and resolved and, if necessary, decision rules in the codebook were refined. With a few exceptions that will be discussed later in this paragraph, the inter-annotator agreement was moderate to almost perfect ($.61 < K > .82$) (cf. Landis & Koch, 1977) as is shown in Appendix C. Pearson correlation coefficients were calculated for number of texts per unit ($N = 14$, $r = .97$, $p < .001$, 86 % agreement) and for number of paragraphs per text ($N = 16$, $r = .99$, $p < .001$, 69 % agreement).

The structure of problem-solution hardly occurred in paragraphs. As a result, disagreements about this structure caused poor agreement between coders. After discussing the disagreements only three paragraphs were assigned to the structure of problem-solution. In the analysis of the assignments, it turned out quite complicated to determine whether the information required for the assignment could be found in the text or not. In many cases some information was provided but the exact answer was not in the text. This explains the fair kappa score of .34. All disagreements were discussed and resolved and definitions in the codebook were sharpened.

3.4 Statistical analysis

The datasets were analyzed using IBM SPSS Statistics version 25. The analyses were completed via general linear univariate models. In the analysis of text structures at the text level and paragraph level we added number of paragraphs respectively number of sentences per paragraph as covariates.

4 Results

This section presents the significant results of our analysis. See Appendix D for an overview of all results.

4.1 Segmentation and text length

The number of texts per teaching unit (see Figure 4) differed between teaching programs ($F(6,70) = 19.28$, $p < .001$). Differences were relatively small as the numbers of texts ranged from an average of 1.00 text per teaching unit in *Natuniek, Natuurzaken*, and *Naut* to

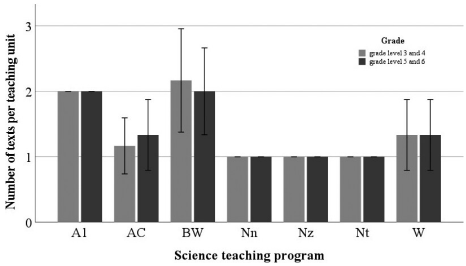

Figure 4 Number of texts per unit

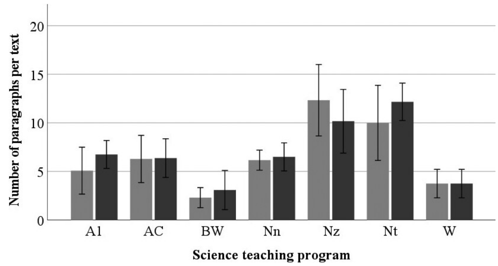

Figure 5 Number of paragraphs per text

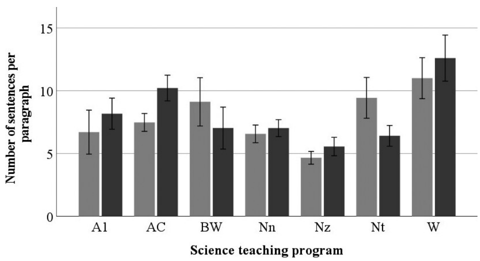

Figure 6 Number of sentences per paragraph

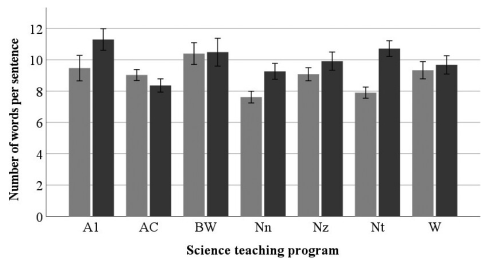

Figure 7 Number of words per sentence

an average of 2.08 texts in *Blink Wereld*. The mean number of paragraphs per text (see Figure 5) also differed between teaching programs (F(6,102) = 24.28, p<.001). *Natuurzaken* (11.25) and *Natuniek* (11.08) displayed the highest number of paragraphs per text (all ps<.001), while the number of paragraphs in *Blink Wereld* (2.72) was lower than that of all other teaching programs (all ps<.003), except *Wijzer* (p = .88). Throughout the corpus 15.5% of the texts consisted of one paragraph.

The length of paragraphs (see Figure 6) differed between teaching programs (F(6,695) = 18.33, p<.001), with mean number of sentences per paragraph ranging from 5.07 in *Natuurzaken* to 11.80 in *Wijzer*. In addition, an interaction effect was found between program and grade level (F(6,695) = 6.13, p<.001). *Argus Clou* (F(1, 93) = 18.35, p<.001) and *Natuurzaken* (F(1,133) = 4.22, p = .04) show an increase in number of sentences per paragraph between grades 3/4 and 5/6, whereas *Naut* shows a decrease between these grade levels (F(1,131) = 12.37, p = .001).

As Figure 7 shows, sentence length differed both between teaching programs (F(6,694) = 11.24, p<.001) and grade levels (F(1,694) = 39.08, p<.001). In addition, an interaction effect of teaching program and grade level was found (F(6,694) = 7.73, p<.001). Four programs revealed a significant increase in number of words per sentence from grade 3/4 to grade 5/6: *Alles-in-1* (F(1,140) = 11.81, p = .001), *Natuniek* (F(1,74) = 27.37, p<.001), *Natuurzaken* (F(1,133) = 5.61, p = .02), and *Naut* (F(1,130) = 78.18, p<.001). In *Argus Clou* the number of words per sentence decreased between these grade levels (F(1,93) = 5.75, p = .02).

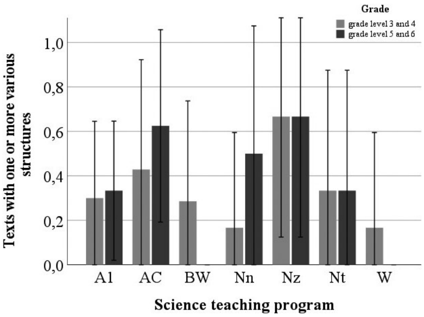

Figure 8 Proportion of texts with one or more types of text structures

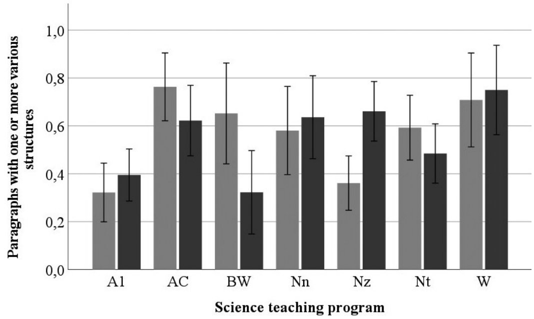

Figure 9 Proportion of paragraphs with one or more types of text structures

These outcomes show that teaching programs differ strongly in segmentation and text length. Some programs present texts with many relatively short paragraphs, others use fewer paragraphs but with more sentences. In addition, programs do not display an increase in text length in terms of a higher number of paragraphs in grades 5/6 than in grades 3/4. However, some programs do show an increase in paragraph length, either in number of sentences per paragraph or in number of words per sentence. Still, this increase in paragraph length is not consistent over programs, as some programs do not display such an increase (*Wijzer*), or the increase in number of sentences in a paragraph comes at the cost of sentence length (*Argus Clou*), or vice versa (*Naut*).

4.2 Text structures

This section describes the outcomes of the structure analysis of the texts and paragraphs. Texts that consisted of only one paragraph (15.5 % of the texts) and paragraphs consisting of one sentence (4 % of the paragraphs) were not taken into account.

We first determined the proportions of texts that included one or more types of text structures (see Figure 8). In most of the 34 cases this concerned texts in which two adjacent paragraphs were involved in a coherence relation. No differences between programs ($F(6,82) = 1.42$, $p = .22$) or grade levels ($F(1,82) = 0.00$, $p = .99$) were found. Out of the 34 texts that included one or more text structures, only 19 texts (56 %) were organized around a top-level structure that covered at least 75 % of all paragraphs. In most cases this was sequence (42 %), followed by problem-solution (26 %), cause-effect (16 %) and comparison (16 %).

The proportions of paragraphs with one or more types of structures (see Figure 9) showed more variation, as we found a main effect of teaching program ($F(6,625) = 4.63$, $p < .001$), as well as an interaction effect of program and grade level ($F(6,625) = 3.35$, $p = .003$). In *Natuurzaken* the proportion of paragraphs with one or more types of structures was higher in the materials for grade 5/6 than in those for grade 3/4 ($F(1,128) =$

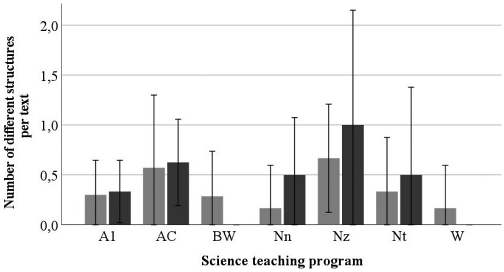

Figure 10 Number of different structures per text

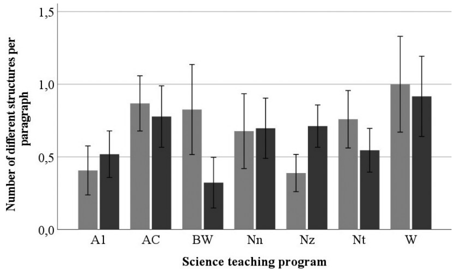

Figure 11 Number of different structures per paragraph

9.71, p = .002), while the other programs did not show differences between grade levels (all ps>.09). In many cases the structure did not cover the whole paragraph, and clear examples as listed in Appendix A were rare. Out of the 336 paragraphs that were assigned to one or more text structures, 35% (n = 112) concerned a single-structured top-level. Here problem-solution (32%) and sequence (28%) were slightly more frequent than cause-effect (22%) and comparison (18%).

Next, we calculated the mean number of different text structures per text (Figure 10), which ranged from .08 (*Wijzer*) to .83 (*Natuurzaken*) with a total average of .39. Again, at the text level no differences were found between programs (F(6,82) = 1.31, p = .26) or grade levels (F(1,82) = 0.12, p = .73).

At the paragraph level the mean number of different text structures (Figure 11) did vary, with a main effect of teaching program (F(6,625) = 2.42, p = .03) and an interaction effect of program and grade level (F(6,625) = 2.64, p = .02). Posthoc comparisons revealed that *Blink Wereld* showed a decrease in mean number of different structures per paragraph between grade levels from .83 to .32 (F(1,51) = 5.03, p = .03), whereas *Natuurzaken* showed an increase from .39 to .71 between grade levels (F(1,128) = 8.31, p = .005).

In order to establish whether all programs would familiarize students with all types of structures, we subsequently determined the frequency in which the four structures occurred in the text parts (see Figures 12 to 19). At the text level, no differences were found with respect to sequence, problem-and-solution, and comparison (all ps>.09), but the proportion of texts with a cause-and-effect structure differed between programs (F(6,83) = 2.23, p = .048). In four programs no examples of texts with a cause-and-effect structure at the text level were found, while *Natuurzaken* showed the highest proportion (.25).

At the paragraph level, differences in the occurrence of structures were found for all text structures except sequence. For cause-and-effect we found a main effect of program (F(6,626) = 4.01, p<.001) and an interaction effect of program and grade level (F(6,626) = 3.51, p<.002). In *Blink Wereld* the proportion of paragraphs with a cause-and-effect structure decreased between grade levels from .61 to .23 (F(1,52) = 9.24, p = .04), while *Natuurzaken* showed an increase from .26 to .44 (F(1,129) = 4.58, p = .03).

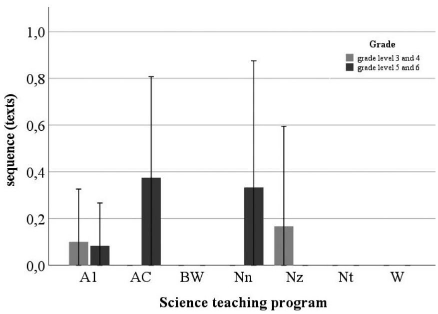

Figure 12 Proportions of texts with a sequential structure

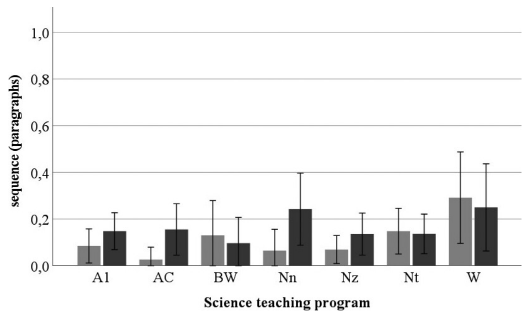

Figure 13 Proportions of paragraphs with a sequential structure

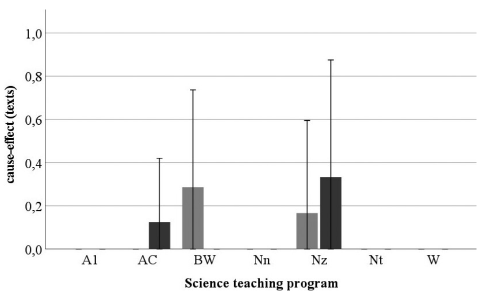

Figure 14 Proportions of texts with a cause-effect structure

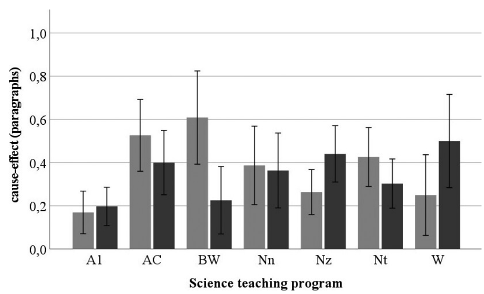

Figure 15 Proportions of paragraphs with a cause-effect structure

Analysis of the proportion of paragraphs with a problem-and-solution structure revealed a main effect of program ($F(6,626) = 4.76$, $p<.001$), grade level ($F(1,626) = 12.58$, $p<.001$) and an interaction between program and grade level ($F(6,626) = 3.11$, $p = .005$). Both *Wijzer* ($F(1, 46) = 5.55$, $p = .02$) and *Natuniek*: ($F(1, 52) = 2.84$, $p = .02$) showed a decrease between grade levels in paragraphs with a problem-and-solution structure.

In addition, programs differed in their application of the comparison structure at the paragraph level ($F(6,626) = 2.39$, $p = .03$). *Alles-in-1* had more paragraphs with a comparison than *Natuurzaken* ($p = .049$), whereas in *Blink Wereld* we found no comparisons at all.

4.3 Layout, introductions and illustrations

Table 3 presents the mean number of texts with a clear layout, the proportion of texts with an introduction, and the proportion of introductions that served as an advance organizer to the content of the text. The type of layout differed between programs ($F(6,102) = 14.01$, $p<.001$). Four programs (*Alles-in-1*, *Natuniek*, *Naut* and *Wijzer*) always presented a clear

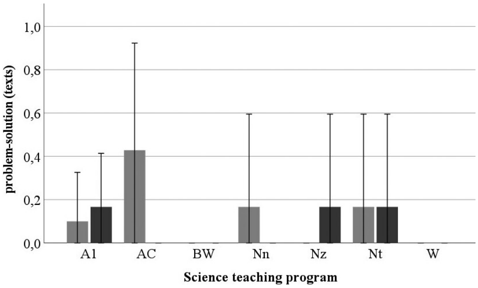

Figure 16 Proportions of texts with a problem-solution structure

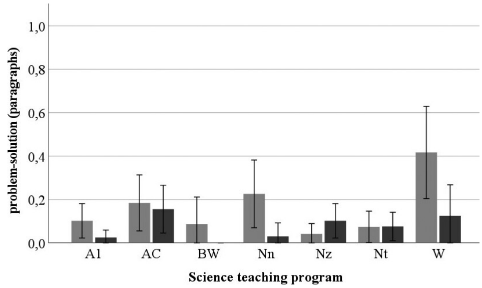

Figure 17 Proportions of paragraphs wit a problem-solution structure

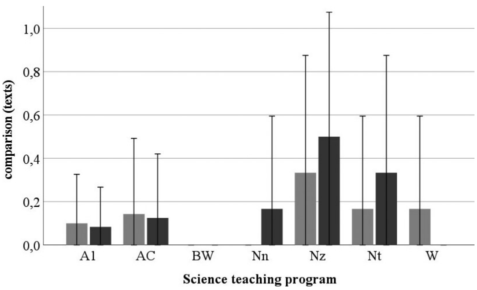

Figure 18 Proportion of texts with a comparison structure

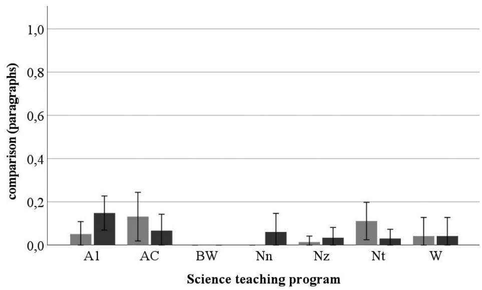

Figure 19 Proportion of paragraphs with a comparison structure

layout, while two programs (*Argus Clou* and *Blink Wereld*) did so in most of the texts. In *Natuurzaken* almost all pages differed in the way the text parts and illustrations were distributed over the pages, making it hard to the reader to easily create a general overview of the text.

Programs also differed in their use of introductions ($F(6,102) = 25.76$, $p<.001$) and the proportion of introductions that functioned as an advance organizer ($F(4,52) = 6.45$, $p<.001$). *Natuniek* and *Naut* always included an introduction that gives a preview of the content of the text, while *Alles-in-1* and *Natuurzaken* did not include introductions at all, and the other three programs varied in their use and function of introductions.

In the corpus we counted 336 paragraphs that captured one or more text structures. The mean proportion of paragraphs accompanied by an illustration that visualizes the rhetorical structure of the text was .14. Table 3 shows the results per teaching program. No differences between science programs or grade levels were found (all $ps<.29$). Most illustrations depicted a sequential structure (46%), or a causal relation (28%). Only a few illustrations showed a problem-solution relation (2%) or a comparison (4%).

Table 3 Proportions (and standard deviations) of texts with a clear layout, of texts with an introduction, of introductions that served as advance organizer, and of paragraphs accompanied by an illustration that visualizes the rhetorical structure of the text

	Texts with a clear layout (n = 116)	Texts with an introduction (n = 116)	Introduction as advance organizer (n = 62)	Paragraphs with an illustration that visualizes its rhetorical structure (n = 336)
Alles-in-1	1.00 (0.00)	0.00 (0.00)	–	0.08 (0.27)
Argus Clou	0.73 (0.46)	0.80 (0.41)	0.58 (0.52)	0.16 (0.37)
Blink Wereld	0.72 (0.46)	0.56 (0.51)	0.57 (0.51)	0.16 (0.37)
Natuniek	1.00 (0.00)	1.00 (1.00)	1.00 (1.00)	0.13 (0.34)
Natuurzaken	0.17 (0.39)	0.00 (0.00)	–	0.15 (0.36)
Naut	1.00 (0.00)	1.00 (0.00)	1.00 (1.00)	0.14 (0.35)
Wijzer!	1.00 (0.00)	0.75 (0.45)	1.00 (1.00)	0.14 (0.36)
Total	0.82 (0.39)	0.53 (0.50)	0.82 (0.39)	0.14 (0.34)

4.4 Assignments

In the analysis of assignments we first determined the proportions of assignments that could be related to one of the four text structures (see Figure 20). A Repeated Measures ANOVA revealed a difference between programs ($F(6,1060) = 2.72$, $p = .01$) and text structures ($F(3,3180) = 61.64$, $p < .001$). A post hoc Tukey test revealed that *Alles-in-1* contained a lower proportion of assignments related to one of the four structures than *Natuniek* ($p = .04$).

As with the paragraphs, the cause-and-effect structure was by far the most frequent in all programs (.18). The other three structures were found less often (sequence: .03, problem-and-solution: .03, comparison: .04).

In most assignments (72%), the information needed to answer the question or to carry out the task could be found in the text, most often at the paragraph level (68%). Sometimes information had to be retrieved from more than one paragraph (23%) and in some cases the information needed was no more than one sentence (9%). For the assignments for which the information was contained in the text, the structure of the text corresponded with the structure that we had linked to the assignment in 48% of the cases. Almost all assignments with a sequential structure concerned the organization of given information, whereas causal relations were often represented in open questions, multiple choice questions, and gap-filling tasks. Dealing with problem-solution was often targeted with a writing task or an open-ended question,

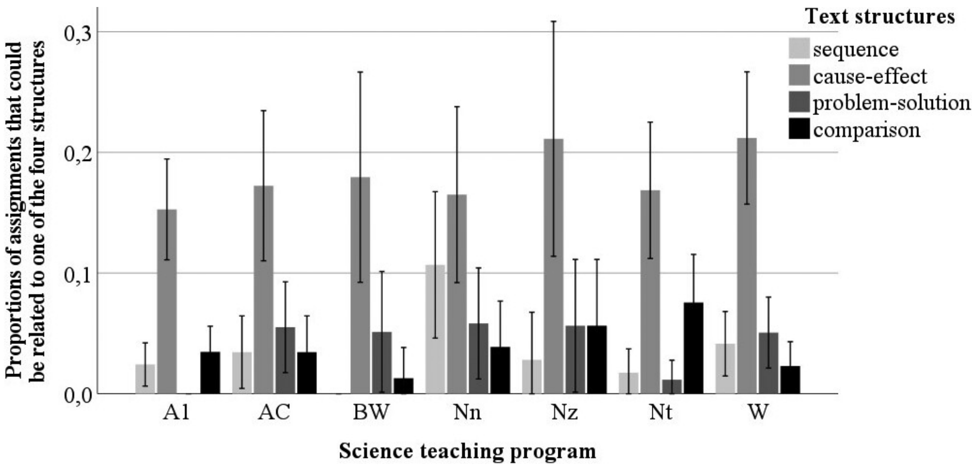

Figure 20 Proportions of assignments related to one of the four text structures, sorted by structure

whereas for comparison programs mostly used open-ended questions or the organization of given information.

5 Conclusions and discussion

On the basis of our literature review, we have argued that it would be worthwhile for Dutch primary education to embed reading instruction in content-area learning, and also teach children about text structures. Before actually starting the implementation of these ideas, and develop educational materials for the Dutch context, we took a step back and focused on the suitability of current science programs and presence of points of departure in this respect. This focus on textbooks is in line with the Component Model of Reading, which stresses that ecological components such as instructional practices, teacher knowledge and textbook content are of relevance in the implementation of reading interventions in educational practice (Aaron et al., 2008; Beerwinkle et al., 2018).

The aim of our study was to determine to what extent current Dutch science teaching textbooks and workbooks used in grades 3–6 are appropriate for text structure instruction. Of course these books were developed primarily for science education and can therefore not be expected to be fully tailored to reading instruction. However, given our plea for the integration of reading instruction and content learning, it is still worth the effort to explore the opportunities of the teaching materials and see if and how they can be improved to make them usable for step-by-step instruction about text structure. The analysis of Dutch materials can be considered a case study that could inspire researchers and educational experts from other countries interested in implementing text structure instruction within science education.

Our first conclusion from the analysis is that the textbooks differed strongly in text length and segmentation. In some textbooks texts were subdivided in many short paragraphs, whereas others presented texts with fewer but longer paragraphs. Publishers of science programs seem to increase the number of words per sentence across grade levels, but most programs do not seem to deliberate increase the complexity of their educational texts by enlarging text length.

Second, we noticed that differences in segmentation interfered with the proportions of text structures we found at the paragraph and the text level. As could be expected, more text structures were found at the text level in texts with multiple paragraphs, and more coherence relations between sentences were found in texts with longer paragraphs. In line with the study of Peti-Stantić (2021) we also conclude that the materials do not show an increase in complexity, since the mean number of different text structures both per text and per paragraph did not increase from grade level 3/4 to grade level 5/6. Programs also differed strongly in other text features such as the use of introductions and clarity of the layout.

Our third conclusion concerns the occurrence of texts with a clear structure. To properly introduce new text structures to students, the use of exemplary, well-organized single-structured texts is recommended (Jones et al., 2016). We did not find many texts that could serve as such model texts. At the text level, text structures most often did not cover more than two paragraphs, and at the paragraph level, most text structures were relations between two sentences and did not cover the whole paragraph. Very clear examples as listed in Appendix A were rare. A similar lack of exemplary single-structured texts was also found in other analyses of textbooks for primary education (Jones et al., 2016; Seifert, 2021).

Furthermore, a systematic introduction and practice of the text structures requires a substantial number of model texts for all text structures. In our corpus materials, not all programs represented all text structures at the text level, and at the paragraph level cause-effect was by far the most frequent structure. Despite great variations in results, probably due to different approaches in operationalization, other researchers also note that different types of text structures were not equally represented in the textbooks they analyzed (Agius & Zammit, 2021; Farris et al., 1988; Jones et al., 2016; Peti-Stantić et al., 2021).

In the analysis of assignments, we found examples of tasks that could support the comprehension of science content and are useful in text structure instruction as well. Such examples are assignments in which students have to fill in graphic organizers, or writing tasks that make students write down the differences and similarities between two subjects. Most assignments, however, were local inference questions such as: "*A rabbit can turn its ears in all directions. Why is that important for the rabbit?*" This type of assignments asks for the comprehension or reproduction of cause-and-effect relations established at the sentence or at best the paragraph level, and hence does not require students to connect information across paragraphs. Although the former approach, with a focus on coherence relations at the sentence level, seems the preferred option for second graders (Williams et al., 2014), the latter is a necessary component of text structure instruction for the higher grades.

From our analysis we can conclude that the materials do offer opportunities for text structure instruction. Close examination of the texts reinforces our assumption that the content of science in many cases indeed matches very well with the basic text structures; topics such as *climate change*, *functions of the body*, *animal survival strategies* or *life cycles of plants and trees* logically ask for patterns of cause-and-effect, problem-and-solution, comparison or sequence. Even so, the current materials are not suitable for a step-by-step implementation and practice of knowledge and skills related to text structure. We would like to highlight the importance of clearly structured texts for both text structure instruction, text comprehension, and content learning (Jones et al., 2016). With a few simple adjustments in the way texts are structured, many texts in the corpus would be easier to understand. Our revision of the paragraph about fossil fuels in Appendix E, which we reorganized according to a problem-solution structure, illustrates how this can be done with relatively few changes. Furthermore, on the basis of our analysis and suggestions from previous research into text structure instruction, we would like to provide the following recommendations for educational publishers:

- Ensure a substantial proportion of all text structures.
- Use short and clear exemplary texts (e.g. of just one paragraph) to introduce and model new text structures, especially in the lower grades.
- Ensure a gradual increase in text complexity by familiarizing students with text structures beyond the paragraph level and/or by increasing the number of structures per text.
- Present texts with a clear layout.
- Add introductions to the text that provide the reader with a preview on the content and structure of the text, and consider the benefits of adding a conclusion to the text.
- Add images that support the understanding of the rhetorical structure of the text.
- Add assignments that match the structure of the text, such as filling in graphic organizers.
- Make use of writing tasks that help students find the main ideas of the text.

According to the Component Model of Reading proposed by Aaron et al. (2008), textbook content is one of the ecological components in the acquisition of literacy skills. Other important ecological components in classroom practice are teacher knowledge and instructional practices (Beerwinkle et al., 2018). Therefore, in pursuit of a better reading proficiency, high quality teaching materials are required, but teachers' knowledge and skills are also of decisive importance. Some research has been conducted on the knowledge, skills and efficacy beliefs of teachers with regards to text structure instruction, showing a lack of knowledge about text structure (Beerwinkle et al., 2018; Reutzel et al., 2016), and revealing that teachers feel uncertain about teaching text structure (Bogaerds-Hazenberg et al., 2022). An analysis of the Dutch language curriculum used for training teachers for primary education also shows that this knowledge base provides insufficient theoretical insights on text structure (Kooiker-den Boer et al., 2019). Future research with regard to the implementation of text structure instruction in primary schools in the Netherlands should therefore also be aimed at teacher knowledge and skills.

In retrospect we can say that our materials analysis has some limitations. First, the significant differences between teaching programs in text length and segmentation combined with our decision to analyze an equal number of teaching units per program unintentionally caused differences in the amounts of text and assignments we analyzed per teaching program. We controlled for this by using number of paragraphs or number of sentences as a covariate in the respective analyses, and the size of our sample is still big enough to make a comparison between programs, but this could be a point of consideration in future research.

Furthermore, we tried to operationalize as precise and unequivocal as possible how to establish the number of texts or paragraphs containing one of the four text structures. This is why we added examples from our corpus materials and a precise description of the practices we applied in this paper. However, outcomes of other studies that analyzed educational textbooks show partially different patterns in the occurrence of text structures. Of course the content of these textbooks might differ, but it would also be useful to compare how these analyses have been conducted and specifically, how the definition of text structures was operationalized. If researchers apply a similar approach it would be easier to compare the outcomes of multiple analyses.

Finally, in our analysis we found that 35 % of all texts and 53 % of the paragraphs included at least one of the four text structures. This means that these texts and paragraphs met the criteria we had set for one or more of the four structures under investigation. We did not analyze how the remaining texts and paragraphs were organized. Given our decision to disregard the 'description' structure, we expect many of these texts to contain descriptions. However, texts could also be organized differently, for instance displaying a claim-argument or a pro-and-con structure. A closer analysis of the way these other texts are organized could shed light on this issue.

In conclusion, our analyses underpin the possibilities that science textbooks offer for the integration of text structure instruction and content learning. We look forward to the development of more materials and materials of higher quality that ensure a gradual introduction of different types of text structures in educational practice.

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We would like to thank dr. Nina Sangers, for serving as a second coder of part of the materials. We are also thankful to the educational publishers who gave us permission to publish part of their materials (i.e. Figures 1–3 and several excerpts from the textbooks) in this manuscript.

Notes

1 Throughout this paper, excerpts from Dutch educational textbooks are represented by their English translations. For *Blink Wereld*, we list relevant unit and lesson numbers instead of page numbers, because its texts come from digital resources without page numbering.

2 In Dutch primary education three content-area subjects are being taught – most often separately, but sometimes in a combined, thematically oriented way: Geography, History and Nature & technology. In this paper we use the term science to refer to this third subject, which includes topics such as the circle of life, energy, food, forests, magnets etc. Nationwide standards for Nature & technology only describe the science content that has to be taught and do not include any literacy learning standards.

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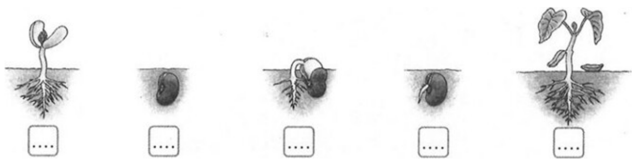
Appendix A – Examples from the teaching materials analyzed

Short description, accompanying signaling words and example of the five most common text structures in expository texts

Description:	***Mosses***
aspects of a topic *Signaling words*: for example, characteristics are	*Mosses can be found everywhere: in the dunes, high in the mountains or just in your garden. Many mosses grow in forests, on rotting wood, or on the ground. They do not have real roots, but take the water directly from the air. There are nearly 10.000 varieties of moss! Moss is the oldest plant species on earth.* (*Alles-in-1*, grade 5/6, p. 63)
Sequence:	***Who eats what?***
time-ordered collection of ideas or events *Signaling words*: first, second, before, dates	*The caterpillar eats the leaves of a cabbage plant. A bird eats the caterpillar. The bird dies and is eaten by benthic animals and fungi. The minerals that remain are used by the plant to grow. The plant is again eaten by the caterpillar. And you can go on like this for a very long time. A cycle of food is created.* (*Naut*, grade 5, p. 32)
Comparison:	***Transparant***
ideas related by differences and/or similarities *Signaling words*: the same as, instead, have in common	*Ice, glass and plastic are a bit alike. You can see through all three materials. Yet they behave very differently. If you jump on a thin plate of ice, it will break. This also happens with glass, but not with plastic. Ice is more likely to melt than plastic.* (*Naut*, grade 4, p. 34)
Cause-effect:	***With strings attached to the sun***
main ideas organized into cause and effect parts *Signaling words*: due to, because, consequence	*The sun is more than a million times the size of the earth and about 300.000 times as heavy. With all that gravity, the sun is pulling the planets. It seems as if they are on a string from the sun. The planets therefore revolve around the sun. This way the solar system stays neatly together.* (*Naut*, grade 4, p. 98)

Problem-solution:	***Air in bottles***
main ideas organized in problem part and solution part *Signaling words:* difficulty, ways to prevent, problem, solution	*We are constantly breathing in and out. To be able to dive for an hour, you need a room full of air. Of course you can't take that with you underwater. Fortunately, air is gas. You can compress gases. The amount of air in a room is made 100 times smaller. So it fits in the bottle on the back of the diver.* (*Naut*, grade 4, p. 36)

Appendix B – Clarification and examples of the analysis of assignments per text structure

<table>
<tr><td>Sequence</td><td>Information has to be organized in a sequential order, for example by describing or drawing a process as in (1) or by putting events or actions in the right order as requested in (2).</td></tr>
<tr><td>1</td><td>Draw the life course of a sunflower. If you like it and have time, you can also do it from a butterfly or a human or … (Alles-in-1, grade 3/4, p. 69)</td></tr>
<tr><td>2</td><td>On the pictures you can see how a new plant grows from a seed. Put the pictures in the correct order. Add numbers 1 through 5. (Argus Clou, grade 5, p. 40)
</td></tr>
<tr><td>Cause-effect</td><td>The question or task requires the understanding of causality or inferring a causal relationship. Both causation and reasoning relationships are included in this analysis. This can be open-ended questions such as (3) and (4), multiple choice questions (5) or gap-filling tasks (6).</td></tr>
<tr><td>3</td><td>Why don’t nomads build houses? (Alles-in-1, grade 3/4, p. 9)</td></tr>
<tr><td>4</td><td>At the insect hotel you will not only find insects. There are also birds. Explain. (Argus Clou, grade 3, p. 5)</td></tr>
<tr><td>5</td><td>Birds of prey have very good eyes. Why is that? Mark the correct answer. Birds of prey have good eyes because:
o They can then eat their prey more easily.
o They can then already see their prey from a great distance.
o They can then better see if the enemy is coming.
o They can then use their beak better. (Natuniek, grade 3, p. 9)</td></tr>
<tr><td>6</td><td>Sick!
Karlijn is ill. She has a fever, stomach ache and diarrhea. Yesterday she had a barbecue. what could have happened? The meat she ate, was not cooked __________
There were sickening ____________in the meat. (Wijzer, grade 3, p. 81)</td></tr>
</table>

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Problem-solution **The question or task requires thinking about one or more solutions to a problem such as for example (7). In our analysis we interpreted 'problem' in a broad sense. This could also be a goal that has to be achieved or a design question as in (8). Multiple choice questions such as (9) were included as well.**

7 If the handles of a pan are also made of steel, you will not be able to grip the pan properly. How can this be solved? What do you think? Write it down. (*Blink Wereld*, grade 4, unit 6.2, lesson 1, worksheet)

8 Design a hut where you stay warm while camping. (*Argus Clou*, grade 5, p. 18)

9 You want to get a lot of carbohydrates and proteins. Which of the two dishes do you choose? Please tick the correct answer.

- o A sandwich with jam.
- o A sandwich with sausage. (*Argus Clou*, grade 3, p. 80)

Comparison Two or more objects or phenomena have to be compared and differences and/or similarities have to be mentioned, as in (10). We only included sorting tasks such as (11) where terms had to be assigned to different categories and certain concepts fit into several categories. Sorting questions where concepts were divided into two or more categories without overlap, as in (12), were not.

10 Find a picture of a recumbent bike. Compare the recumbent bike with a regular bike.
What is the same? What's different? (*Naut*, grade 3, p. 63)

11 What belongs to the bulb? And what belongs to the corm? Check the correct answers.
Note: some words belong both to the bulb and the corm. (*Argus Clou*, grade 3, p. 4)

	bulb	corm
There is nutrition in it.		
A flower grows out.		
Has layers like an onion.		
Thick piece of the stem.		

12 What transmits infrared and what receives infrared? Write these words in the appropriate box: television – human – remote control – sun – heat camera – radiator
(*Wijzer*, grade 6, p. 40)

Transmits infrared	Receives infrared

Appendix C – Inter-annotator agreement (Cohen's kappa and % agreement) per feature coded

Features coded	Cohen's kappa	% agreement
Texts (N = 16)		
Text structure: Sequence	.61	88
Text structure: Cause-effect	.77	94
Text structure: Problem-solution	.61	88
Text structure: Comparison	.64	81
Layout	.82	94
Presence of introduction	.75	88
Function of introduction	.80	75
Paragraphs (N = 67)		
Text structure: Sequence	.70	90
Text structure: Cause-effect	.66	90
Text structure: Problem-solution	.00	93
Text structure: Comparison	.80	94
Illustrations (N = 67)	.73	90
Assignments (N = 110)		
Structure of assignment (N = 110)	.77	91
Information in the text? (N = 25)	.34	72
Text level of information (N = 12)	.77	92
Match with structure of the text (N = 12)	1.00	100

Appendix D – Results from the statistical analyses

Table A Statistical details for various text length variables

Factor	Program			Grade level			Program*Grade level		
	F	df	p	F	df	p	F	df	p
Number of texts per unit	19.28	6, 70	< .001	0.00	1, 70	1.00	0.20	6, 70	.98
Number of paragraphs per text	24.28	6, 102	<.001	0.62	1, 102	.43	0.98	6, 102	.45
Number of sentences per paragraph	18.33	6, 695	<.001	0.61	1, 695	.44	6.13	6, 695	<.001
Number of words per sentence	11.24	6, 694	<.001	39.08	1, 694	<.001	7.73	6, 694	<.001

Table B Statistical details for variables aimed at the analysis of text structure

Factor	Program			Grade level			Program*Grade level		
	F	df	p	F	df	p	F	df	p
Proportion of texts with one or more types of text structures	1.42	6, 82	.22	0.00	1, 82	.99	0.69	6, 82	.66
Proportion of paragraphs with one or more types of text structures	4.63	6, 625	<.001	0.34	1, 625	.56	3.35	6, 625	.003
Number of different structures per text	1.31	6, 82	.26	0.12	1, 82	.73	0.73	6, 82	.63
Number of different structures per paragraph	2.42	6, 625	.03	2.03	1, 625	.15	2.64	6, 625	.02
Proportions of texts with a sequential structure	1.17	6, 83	.33	1.84	1, 83	.18	1.91	6, 83	.09
Proportions of paragraphs with a sequential structure	1.88	6, 626	.08	2.98	1, 626	.09	1.05	6, 626	.39
Proportion of texts with a cause-effect structure	2.23	6, 83	.05	0.00	1, 83	.99	1.17	6, 83	.33
Proportion of paragraphs with a cause-effect structure	4.01	6, 626	.001	0.52	1, 626	.47	3.51	6, 626	.002
Proportion of texts with a problem-solution structure	0.93	6, 83	.48	0.67	1, 83	.42	1.48	6, 83	.20
Proportion of paragraphs with a problem-solution structure	4.76	6, 626	<.001	12.58	1, 626	<.001	3.11	6, 626	.005
Proportion of texts with a comparison structure	1.92	6, 83	.09	0.34	1, 83	.56	0.42	6, 83	.87
Proportion of paragraphs with a comparison structure	2.39	6, 626	.03	0.05	1, 626	.82	2.03	6, 626	.06

Table C Statistical details for variables aimed at the analysis of layout, introductions and illustrations

Factor	Program			Grade level			Program*Grade level		
	F	df	p	F	df	p	F	df	p
Proportion of texts with a clear layout	14.01	6, 102	<.001	0.31	1, 102	.58	0.66	6, 102	.68
Proportion of texts with an introduction	28.48	6, 102	<.001	0.00	1, 102	.98	0.25	6, 102	.96
Proportion of introductions as advance organizer	6.45	4, 52	<.001	0.81	1, 52	.37	1.71	4, 52	.16
Proportion of paragraphs accompanied by an illustration visualizing the text structure	0.26	6, 322	.96	0.00	1, 322	.97	1.23	6, 322	.29

Table D Statistical details for variables aimed at the analysis of assignments

Factor	Program			Grade level			Program*Grade level		
	F	df	p	F	df	p	F	df	p
Proportion of assignments related to one of the four text structures	2.72	6, 1060	.01	0.54	1, 1060	.46	1.29	6, 1060	.26
Proportion of assignments related to a sequential structure	3.47	6, 1060	.002	0.39	1, 1060	.53	1.69	6, 1060	.12
Proportion of assignments related to a cause-effect structure	0.73	6, 1060	.63	1.54	1, 1060	.22	1.91	6, 1060	.08
Proportion of assignments related to a problem-solution structure	3.51	6, 1060	.002	0.01	1, 1060	.92	1.07	6, 1060	.38
Proportion of assignments related to a comparison structure	1.72	6, 1060	.11	0.06	1, 1060	.81	0.66	6, 1060	.68

Appendix E – Two versions of a paragraph about fossil fuels

Unstructured version	**Version with a problem-solution structure**
PRECIOUS ENERGY *You hear a lot about green electricity and environmental-friendly energy. This usually concerns wind energy or solar energy. But why is everyone so concerned about it? It's going well now, isn't it? If we plug a device in, it just starts to work. Nothing to worry about.* The power we use is indeed just fine. Even if it is not 'green'. [Part about how electricity is generated.] It's about heating that water. This is often done with coal, natural gas or petroleum. And that's what we wanted to talk about. Coals are in the ground. They are dug out in mines. They are remains of plants that have hardened after millions of years. You can burn coal. This way you can heat something. An old-fashioned stove, for example. **Gone = gone** Natural gas and petroleum are also in the ground. They are good fuels, just like coal. For example, they make petrol and plastic from petroleum. You can cook, heat or drive a car on natural gas. The problem is that fuels like this can run out. At some point there will be no more coal or petroleum. That's why we have to be careful with it. The advantage of wind, water and the sun is that they never run out. Another disadvantage is that when oil and coal are burned, many dirty substances are released that pollute the air. Burning these substances also causes the greenhouse effect to increase and the temperature on earth to rise. So now you know why electric cars are better for the environment than petrol cars. Especially if they run on green energy!	**PRECIOUS ENERGY** *You hear a lot about green or environmental-friendly energy. This usually concerns wind energy or solar energy. But why should we use green energy? What's the problem with other types of electricity?* Using electricity in itself is just fine, even if it is not 'green'. [Part about how electricity is generated.] It's about heating that water. This is often done with coal, natural gas or petroleum. And that's what causes problems. **Gone = gone** Coals are in the ground. They are remains of plants that have hardened after millions of years. They are dug out in mines. By burning coal, you can heat something. An old-fashioned stove, for example. Natural gas and petroleum are also in the ground. They are good fuels, just like coal. For example, petroleum can be used to make petrol or plastic. And natural gas can be used to drive a car, cook or heat something. The problem is that fuels like these can run out. At some point there will be no more coal or petroleum. Also, when oil and coal are burned, many dirty substances are released that pollute the air. This causes the greenhouse effect to increase, and the temperature on earth to rise. Therefore, it is better for the environment to drive electric cars, especially when they run on green electricity. The advantage of electricity generated by wind, water or the sun is that it never runs out.